Proceedings of the Indiana Academy of Science

1921

PROCEEDINGS

OF THE

Indiana Academy of Science

1921

F. PAYNE, Editor

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CONSTITUTION.

ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other sources and riches of the State; to arrange and prepare for publication such reports of investigation and discussion as may further the aims and objects of the Academy as set forth in these articles.

WHEREAS, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members, and active members.

SEC. 2. Any person engaged in any department of scientific work, or in any original research in any department of science, shall be eligible to active membership. Active members may be annual, life members or patrons. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars and thereafter an annual fee of one dollar. Any person who shall at one time contribute fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Any person who shall at one time contribute one hundred dollars to the funds of this academy may be elected patron, who shall be a life member of the Academy, free of dues. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Application for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary, Editor, and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of the Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past President, together with the officers and Executive Committee, shall constitute the council of the Academy, and represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

SEC. 2. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

8. An Editor shall be elected from year to year. His duties shall be to edit the annual Proceedings. No allowance shall be made to the Editor for clerical assistance on account of any one edition of the Proceedings in excess of fifty ($50) dollars, except by special action of the Executive Committee. (Amendment passed December 8, 1917.)

INDIANA ACADEMY OF SCIENCE.

OFFICERS, 1921

President,
HOWARD E. ENDERS.

Vice-President,
F. M. ANDREWS.

Secretary,
WALTER N. HESS.

Assistant Secretary,
HARRY F. DIETZ.

Press Secretary,
FRANK B. WADE.

Treasurer,
WILLIAM M. BLANCHARD.

Editor,
F. PAYNE, 1921 Proceedings.

Executive Committee:

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ARTHUR, J. C.
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BRUNER, H. L.
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WRIGHT, JOHN S.

Curators:

BOTANY	J. C. ARTHUR
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COMMITTEES ACADEMY OF SCIENCE, 1921.

Program.

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Nominations.

H. L. BRUNER, Butler College, Indianapolis.

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Biological Survey.

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J. J. DAVIS, West Lafayette.

WILL SCOTT, Bloomington.

State Library.

AMOS W. BUTLER, State House, Indianapolis.

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Distribution of Proceedings.

WALTER N. HESS, Greencastle.

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Membership.

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Relations of Academy to the State.

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GLENN CULBERTSON, Hanover.

JOHN S. WRIGHT, Indianapolis, care Eli Lilly & Co.

AMOS W. BUTLER, State House, Indianapolis.

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GLENN CULBERTSON, Hanover.

W. A. MCBETH, Terre Haute.

S. F. BALCOM, Indianapolis.

MEMBERS.*

FELLOWS.

Aley, Robert J., Indianapolis....1908
Andrews, F. M., 110 E. Tenth St., Bloomington....†1911
Arthur, Joseph C., 915 Columbia St., Lafayette....1893
Badertscher, J. A., 312 Fess Ave., Bloomington....1917
Beede, Joshua W., 404 W. Thirty-eighth St., Austin, Texas....1906
Behrens, Charles A., 217 Lutz Ave., West Lafayette....1917
Bennett, Lee F., 309 S. Ninth St., Janesville, Wis....1916
Benton, Geo. W., 100 Washington Sq., care American Book Co., New York, N. Y....1896
Bigney, Andrew J., Evansville....1897
Blanchard, William M., 1008 S. College Ave., Greencastle....1914
Blatchley, W. S., 1558 Park Ave., Indianapolis....1893
Breeze, Fred J., Muncie....1910
Bruner, Henry Lane, 324 S. Ritter Ave., Indianapolis....1899
Bryan, William Lowe, Bloomington....1914
Butler, Amos W., 52 Downey Ave., Irvington, Indianapolis....1893
Cogshall, W. A., 423 S. Fess Ave., Bloomington.
Coulter, Stanley, 213 S. Ninth St., Lafayette....1893
Culbertson, Glenn, Hanover....1899
Cummings, Edgar Roscoe, 327 E. Second St., Bloomington....1906
Deam, Charles C., Bluffton....1910
Dryer, Charles R., Oak Knoll, Fort Wayne....1897
Dutcher, J. B., 1212 Atwater St., Bloomington....1914
Eigenmann, Carl H., 630 Atwater St., Bloomington....1893
Enders, Howard E., 249 Littleton St., West Lafayette....1912
Evans, Percy Norton, 302 Waldron St., West Lafayette....1901
Fisher, Martin L., 325 Vine St., West Lafayette....1919
Foley, Arthur L., Bloomington....1897
Hessler, Robert, Logansport....1899
Hufford, Mason E., 710 Atwater St., Bloomington....1916
Hurty, John E., 31 E. Eleventh St., Indianapolis....1910
Hyde, Roscoe Raymond, 4101 Penhurst Ave., Baltimore, Md....1909
Jackson, Herbert S., West Lafayette....1919
Koch, Edward W., Buffalo, N. Y....1917
Logan, Wm. N., 924 Atwater St., Bloomington....1917
McBeth, Wm. A., 1905 N. Eighth St., Terre Haute....1904
McBride, Robert W., 1239 State Life Building, Indianapolis....1916
Markle, M. S., Richmond....1919

* Every effort has been made to obtain the correct address of each member. The omission of an address indicates that mail addressed to the last printed address was returned as undeliverable; information as to the present address of members so indicated is requested by the secretary. The custom of dividing the list of members has been followed.

† Date of election.

Middleton, Arthur R., 705 Russell St., West Lafayette.............1918
Moenkhaus, W. J., Bloomington.................................1901
Mottier, David M., 215 Forest Place, Bloomington..................1893
Naylor, Joseph P., Greencastle.................................1903
Nieuwland, J. A., Notre Dame.................................1914
Payne, F., 620 Ballantine Road, Bloomington.....................1916
Ramsey, Rolla R., 615 E. Third St., Bloomington.................1906
Rettger, Louis J., 31 Gilbert Ave., Terre Haute.................1896
Rothrock, David A., 1000 Atwater St., Bloomington...............1906
Schockel, Barnard, Terre Haute.................................1917
Scott, Will, Bloomington.....................................1914
Shannon, Charles W., 518 Lahoma Ave., Norman, Okla...........1912
Smith, Albert, 500 University St., West Lafayette................1908
Smith, Charles Marquis, 152 Sheetz St., West Lafayette...........1912
Stoltz, Charles, 530 N. Lafayette St., South Bend.................1919
VanHook, James M., 639 N. College Ave., Bloomington...........1911
Wade, Frank Bertram, 1039 W. Twenty-seventh St., Indianapolis...1914
Williamson, E. B., Bluffton.....................................1914
Wright, John S., care of Eli Lilly & Co., Indianapolis.............1894

NON-RESIDENT MEMBERS AND FELLOWS.

Abbott, G. A., Grand Forks, N. D., Fellow.......................1908
Aldrich, John Merton, Washington, D. C., Fellow................1918
Brannon, Melvin A., Beloit, Wis.
Burrage, Severance, Denver, Colo., Fellow.......................1898
Campbell, D. H., Stanford, Cal.
Clark, Howard Walton, U. S., Biol. Station, Fairport, Iowa.
Cook, Mel T., New Brunswick, N. J., Fellow.....................1902
Coulter, John M., University of Chicago, Illinois, Fellow..........1893
Davis, B. M., Oxford, Ohio.
Evermann, Barton Warren, Golden Gate Park, San Francisco, Cal.
Goss, William Freeman M., 61 Broadway, N. Y., Fellow...........1893
Greene, Charles Wilson, 814 Virginia Ave., Columbia, Mo.
Hargitt, Charles W., 909 Walnut St., Syracuse, N. Y.
Hay, Oliver Perry, U. S. National Museum, Washington, D. C.
Jordan, David Starr, Stanford, Cal.
Kingsley, John S., Urbana, Ill.
Knipp, Charles T., 915 W. Nevada St., Urbana, Ill.
MacDougal, Daniel Trembly, Tucson, Ariz.
McMullen, Lynn Banks, 641 Euclid Ave., Valley City, N. D.
Marsters, Vernon F., Kansas City, Mo., care of C. N. Gould, Fellow..1893
Miller, John Anthony, Swarthmore, Pa., Fellow...................1904
Moore, George T., St. Louis, Mo.
Noyes, William Albert, Urbana, Ill., Fellow.....................1893
Ransom, James H., Detroit, Mich., Fellow.......................1902
Reagan, Albert B., Kayenta, Ariz.
Smith, Alexander, care of Columbia University, New York City, Fellow 1893

Springer, Alfred, 312 E. Second St., Cincinnati, Ohio.
Swain, Joseph, Swarthmore, Pa., Fellow........................1898
VonKleinsmid, R. B., Tucson, Ariz.
Waldo, Clarence A., Fellow (address not known)..................1893
Wiley, Harvey W., Woodward Building, Washington, D. C........1895
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Acre, Harlan Q., Gordon, Nebr.
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Gillum, Robert G., Terre Haute.
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Huber, Leonard L., Hanover.
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Kern, Frank D., State College, Pa.
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Knotts, Armanis F., Anglis, Fla.
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Liston, Jesse G., R. F. D. 2, Lewis.
Ludwig, C. A., Clemson College, S. C.
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McIntosh, Arthur C., 111 N. Dunn St., Bloomington.
Mahin, Edward G., 27 Russell St., West Lafayette.
Mains, E. B., 212 S. Grant St., West Lafayette.
Malott, Burton J., Indianapolis, care of Technical High School.
Malott, Clyde A., 521 E. Second St., Bloomington.
Mason, Thomas E., 130 Andrew Place, West Lafayette.
Mellon, M. G., 403 Russel St., W. Lafayette.
Miller, John W., 444 Littleton St., West Lafayette.
Moore, Kenneth W., 125 Downey Ave., Indianapolis.
Morgan, Frank W., Science Hall, Valparaiso.
Morgan, Will, University Heights, Indianapolis.
Morrison, Harold, Bureau of Entomology, Washington, D. C.
Morrison, Louis A., East Lansing, Mich.
Muldoon, Hugh C., 361 Garfield St., Valparaiso.
Munro, George W., 202 Waldron St., West Lafayette.
Myers, B. D., 321 N. Washington St., Bloomington.
Nelson, Ralph E., 232 Littleton St., West Lafayette.
Nicholson, Thomas E., 519 N. Fess Ave., Bloomington.
Niles, Edward H., 4450 Guilford Ave., Indianapolis.
Noyes, Harry A., Westfield, N. Y., care Welch Grape Juice Co.
O'Neal, Claude E., Forrest Ave., Delaware, Ohio.
Oberdoerfer, Rev. P. Benedict, St. Bernard College, St. Bernard, Ala.
Oberholser, Harry C., U. S. National Museum, Washington, D. C.
Orahood, Harold, Kingman.
Orton, Clayton R., State College, Pa.
Owen, D. A., 200 S. State St., Franklin.
Painter, Henry R., Box 95, West Lafayette.
Pearson, George B., Box 95, West Lafayette.
Peffer, Harry C., 1022 Seventh St., West Lafayette.

Petry, Edward J., 722 E. Eighth St., Brookings, S. D.
Pickett, Fermen L., Pulman College, Station 36, Washington.
Pinkerton, Earl, Box 411, Walters, Okla.
Pollard, Cash B., 419 W. Wood St., Lafayette.
Prentice, Burr N., 400 Russell St., West Lafayette.
Pressey, S. L., Ohio State University, Department of Psychology, Columbus, Ohio.
Pressey, Mrs. S. L., Ohio State University, Department of Psychology, Columbus, Ohio.
Price, Walter A., 123 Sheetz St., West Lafayette.
Proulx, Edward G., 111 Waldron St., West Lafayette.
Rabb, Albert L., 1354 Lemcke Annex, Indianapolis.
Rawles, William P., 924 E. Third St., Bloomington.
Reagan, Albert B., Kayenta, Ariz.
Records, Ralph L., Edinburg.
Reeves, John R., 1022 E. Third St., Bloomington.
Reichert, Joseph S., 522 E. Indiana Ave., South Bend.
Richards, Aute, Norman, Okla.
Richards, Mildred Hoge, Norman, Okla.
Ridgway, Robert, 1030 S. Morgan St., Olney, Ill.
Rifenburgh, S. A., Valparaiso.
Riley, Katherine, Robert Long Hospital, Indianapolis.
Roark, Louis, Box 1266, Okmulgee, Okla.
Roberts, Chester R., Hougham St., Franklin.
Sheak, Wm. H., 154 N. Twenty-first St., Philadelphia, Pa.
Sherman, George W., 4 Murdock Flats, West Lafayette.
Shonle, Horace A., Indianapolis, care Eli Lilly & Co.
Showalter, Ralph W., Indianapolis, care Eli Lilly & Co.
Siever, Winifred, 14 Audubon Court, Indianapolis.
Silvey, Oscar W., College Station, Texas.
Smith, Charles Piper, 354 S. Tenth St., Jan Jose, Cal.
Smith, Ernest R., Greencastle.
Smith, John E., Route 6, Franklin.
Smith, Paul R., University of Pennsylvania, Department of Physics West Philadelphia, Pa.
Snodgrass, Robert E., 2063 Park Road, Washington, D. C.
Spitzer, George, 1000 Seventh St., West Lafayette.
Spong, Philip, 3873 E. Washington St., Indianapolis.
Stacy, Allan R., 1555 Ashland Ave., Indianapolis.
Stone, Ralph B., 307 Russell St., West Lafayette.
Sulzer, Elmer G., Madison.
Suter, E. M., 1437 Broadway, Ft. Wayne.
Tatlock, Myron W., Indianapolis, care Shortridge High School.
Telfer, Margaret, 403 W. 5th St., Bloomington.
Terry, Dr. Oliver P., 215 Sheetz St., West Lafayette.
Tetrault, Philip A., 607 University St., West Lafayette.
Test, Louis A., 222 North St., West Lafayette.
Tevis, Emma L., 122 W. Eighteenth St., Indianapolis.
Thompson, Clem O., Hanover.
Thompson, James T., 334 Lafayette Ave., Lebanon.

Thornburn, A. D., 105 N. High St., Indianapolis.
Thurston, Emory Wright, 4144 Carrollton Ave., Indianapolis.
Treat, Frank M., Atwater Ave., Bloomington.
Troop, James, 123 Sheetz St., West Lafayette.
Tucker, William Motier, Bloomington.
Turner, B. B., 1017 Park Ave., Indianapolis.
Turner, William P., 222 Lutz Ave., West Lafayette.
Turney, Harold E., Department of Conservation, State House, Indianapolis.
Vischer, Stephen S., 817 E. 2nd St., Bloomington.
Voorhees, Herbert S., 804 Wildwood Ave., Ft. Wayne.
Walker, Enos G., 453 College Ave., Valparaiso.
Wallace, Frank N., Department of Entomology, State House, Indianapolis.
Weatherwax, Paul, 416 S. Dunn St., Bloomington.
Weems, Mason L., 102 Greenfield Ave., Valparaiso.
Wenninger, Rev. Francis J., Notre Dame.
Wiancko, Alfred T., 230 S. Ninth St., Lafayette.
Wildman, Ernest A., Richmond.
Wildasin, Pearl D., Kentland.
Wiley, Ralph B., 227 Russell St., West Lafayette.
Wilhite, Miss Ida B., Butler College, Indianapolis.
Williams, A. A., Valparaiso.
Williamson, Jesse H., Bluffton.
Wilson, Arthur J., 901 W. Wabash St., Crawfordsville.
Wilson, Geo. B., 330 Fowler St., West Lafayette.
Wilson, Mrs. Etta S., 2 Clarendon Ave., Detroit, Mich.
Wilson, Ira T., 520 Kirkwood Ave., Bloomington.
Winkenhofer, Walter, Huntingburg.
Witmer, Samuel W., 1405 Ninth St., Goshen.
Wolfe, Harold E., 314 N. Washington St., Bloomington.
Wood, Harry W., Bloomington.
Woodruff, Albert E., Butler College, Indianapolis.
Wright, William L., Indianapolis, care Eli Lilly & Co.
Wynn, Dr. Frank B., 421 Hume-Mansur Bldg., Indianapolis.
Young, Gilbert A., 739 Owen St., Lafayette.
Young, Paul A., 619 S. Randolph St., Garrett.
Yuncker, Truman G., Wood St., Greencastle.
Zebrowski, George, 521 State St., West Lafayette.
Zehring, William A., 303 Russell St., West Lafayette.
Zerfas, Leon G., Indiana University Medical School, Indianapolis.

Fellows	56
Members, Active	268
Members and Fellows, Non-resident	34
Total	358

Minutes of the Spring Meeting.

Indianapolis, Indiana.

Members of the Indiana Academy of Science, the Indiana Audubon Society, and the Nature Study Club of Indiana met in joint session for the first time in the history of the organizations. This meeting afforded the members of all three organizations an opportunity to meet together in a more or less informal way, and to enjoy the many interesting regions surrounding our capital city.

The meeting was planned for two days, Friday and Saturday, May 27th and 28th.

Friday, May 27.

Members of the three societies and their friends met in Fairview Park at 9:30 a. m., and under the direction of Dr. Wynn, and others, all joined in a hike along the towpath to the home of Dr. Cole, where they walked over the beautiful grounds of this magnificent country estate. From Dr. Cole's place, the party tramped to Holliday Park, where everyone enjoyed a delightful hospitality at the home of John F. Holliday. After picnic lunches were eaten, a short, informal program was held in charge of the Audubon Society.

At 2:00 p. m. the party proceeded across country to Bacon's Swamp, entering from the Fifty-sixth Street entrance, and emerging from the Fifty-ninth. Short talks were given by Dr. Dunn and Dr. Blatchley concerning the history and early formation of the swamp.

At 6:30 o'clock covers were laid for seventy-eight members and guests at Ma-Lo Place, where an excellent checken dinner was greatly enjoyed by all. Immediately after dinner a business meeting was held, followed by talks by Dr. Wiley and lantern slides of South America by E. B. Williamson.

Saturday, May 28.

Starting from Indianapolis at 8:00 a. m., the day was spent at Fort Benjamin Harrison, the Boy Scouts' Reservation and Buzzards' Roost. The visit to the fort gave many of the party an opportunity to see, first hand, an army post.

A short tramp from the fort brought the party to the Boy Scouts' Reservation. Here members of the party were greatly delighted to see the beautiful park that Indianapolis has provided for the enjoyment, yes, preservation, of her boys.

Most of the afternoon was spent at Buzzards' Roost. The chief feature of today's program was the unveiling of a memorial tablet to William Watson Woollen, the tablet being on a large boulder in the wooded tract which has been given by Mr. Woollen to the city of Indianapolis for a nature study park. Although the program was in charge of the Nature Study Club, Prof. Enders and Dr. Coulter represented the Academy on the program. Dr. Wynn announced and requested that hereafter the park, instead of being called Buzzards' Roost, be called "Woollen's Garden of Birds and Botany."

The program was concluded at 4:30 p. m., and the meeting adjourned immediately.

Business Meeting.

Indianapolis, Ind., May 27, 1921.

After the dinner, which was served at 6:30 o'clock at Ma-Lo Place, the meeting was called to order by the President, Howard E. Enders.

The following members of the Academy were present:

Flora Anderson
S. F. Balcom
A. R. Becktel
A. J. Bigney
W. S. Blatchley
H. L. Bruner
Elizabeth Downhour
Howard E. Enders
R. C. Friesner
W. A. Guthrie
J. W. Hadley
Walter N. Hess
Robert W. McBride
F. Payne
J. M. VanHook
Frank N. Wallace
Pearl Wildasin
E. B. Williamson
Jesse Williamson
H. W. Wiley
Frank B. Wynn

In the absence of Mr. Harry F. Dietz, chairman of the Membership Committee, the Secretary proposed the names of six persons who were duly elected to membership:

Emma T. Bodine, 4 Mills Place, Crawfordsville, Ind.
Emil Dietz, 334 Congress Ave., Indianapolis, Ind.
George B. Eisenhard, Culver Military Academy, Culver, Ind.
Mrs. George B. Eisenhard, Culver, Ind.
Winifred Siever, 14 Audubon Court, Indianapolis, Ind.
Harold E. Turkey, Department of Conservation, Indianapolis, Ind.

Dr. Frank Wynn, as chairman of the State Historical and Archaeological Survey Committee, announced that a questionnaire had been prepared for the purpose of interesting as many people as possible in the work of this committee, with the hope that many members of the Academy would co-operate in collecting data of a historical and archaeological nature in the State of Indiana. After discussing the nature and purpose of the questionnaire, a copy was presented to each member.

Prof. Payne announced that the 1919 Proceedings were in press and would be ready for distribution in a few weeks. He called the attention of the Academy to the fact that the failure to get this issue published a year ago was not due to any fault of his, as editor, but that it was due to the inability of the state printer to get the issue printed before the date on which the funds reverted to the State.

The President discussed briefly the history of the spring meetings of the Academy, after which he called for suggestions for next year's meeting.

Mr. Charles Stoltz urged that a meeting be held again, as soon as possible, at the Dunes, in order to stimulate interest in the State relative to preserving the Dunes as a state park.

Mr. Eisenhard invited the societies to Culver. He stated that the school would gladly provide tents for the accommodation of visitors.

Mr. Balcom suggested a certain park near Anderson that is noted for its archaeological remains.

Mr. Robert W. McBride presented a resolution with reference to the preservation of Bacon's Swamp, as follows:

> RESOLVED, "That the members of the Indiana Academy of Science, the Indiana Audubon Society, and The Nature Study Club have inspected Bacon's Swamp and its surroundings, and have been impressed by its fitness for the preservation of many forms of wild life where they are of easy access; therefore, be it
>
> RESOLVED, That we heartily and without reserve approve and commend the suggestion that its ownership be acquired by the State, or by the city of Indianapolis, and that it be set aside and protected, and all of its natural beauties, and all of its wild life be preserved for the benefit of the people."

After a brief talk by Dr. Harvey W. Wiley, the business session adjourned at 9:20 p. m., after which Mr. E. B. Williamson entertained the societies with a large number of lantern slides of the country in South America where he has been collecting dragon-flies.

HOWARD E. ENDERS, President.
WALTER N. HESS, Secretary.

MINUTES OF THE WINTER MEETING.

CLAYPOOL HOTEL, INDIANAPOLIS, DECEMBER 1, 1921.

MEETING OF THE EXECUTIVE COMMITTEE.

The Executive Committee was called to order at 8:00 p. m. in Room 200, by President H. E. Enders. The following members were present.

F. M. Andrews
S. F. Balcom
W. M. Blanchard
H. L. Bruner
F. J. Breeze
Amos Butler
W. A. Cogshall
H. F. Dietz
C. R. Dryer
C. H. Eigenmann
H. E. Enders
R. C. Friesner
Walter N. Hess
R. L. Hessler
H. S. Jackson
Robt. W. McBride
D. M. Mottier
J. P. Naylor
E. B. Wiliamson
John S. Wright

The minutes of the last meeting of the Executive Committee were read and approved.

Committee reports were considered as follows:

Program Committee—R. C. Friesner presented the printed program of 85 titles to be read at the present meetings. He called attention to the fact that this year's program reads "The 37th Annual Meeting" while last year's program read "The 35th Anniversary Meeting". At first, it might seem to some that there is a mistake, but such is not so. A different method of reckoning meetings has been used. A slight

change in rooms was announced, in that all meetings scheduled to be held in Parlor B during the forenoon of December 2d, would be held in Room 200. Attention was called to the fact that we need more than one day for our meetings because of the large number of papers that have to be crowded into so short a space of time. No action was taken, but it was the sense of the Executive Committee that the matter should be left with the Program Committee, and that the number of papers presented for reading at any one session should aid the committee in solving this problem.

R. C. Friesner raised the question about the purchase of a lantern. He stated that the Academy now has to rent a lantern each year at a very high cost. No action was taken, but W. A. Cogshall stated that Indiana University would gladly send up a lantern at any time if given two days' notice. W. M. Blanchard made a similar offer for DePauw.

The advisability of holding our meetings in several sections instead of two, as is done at present, was up for discussion. It was shown that if this was done, better facilities than those offered by the Claypool Hotel would have to be sought.

Committee on Nominations—No report until tomorrow.

Biological Survey—H. S. Jackson revised his announcement of two years ago concerning the relation of this work to that of the Conservation Commission. He stated that Mr. Lieber of this commission had been made a member of the Biological Survey Committee. The desirability of making such a survey in the State of Indiana was discussed, after which Mr. Jackson suggested that a definite effort should be made by the Academy to obtain a special appropriation for this work. He urged that a committee, composed of the more influential members of the Academy, should be selected to go before the state legislature to obtain such funds. D. M. Mottier spoke of the advisability of informing the members of the legislature of the past work of a biological survey nature that has been done up to the present time. Amos Butler moved that it be the sense of the Executive Committee that the report of this committee be approved and carried out. Motion passed. He then advised that an effort be made to get the Governor's approval and his active cooperation solicited.

The following members were named to represent the Academy in soliciting the state legislature for funds for the work of the Biological Survey Committee:

R. W. McBride.
F. B. Wynn.
A. W. Butler.
Stanley Coulter.

H. S. Jackson asked for an expression of opinion as to the desired relationship that should exist between this committee and that of the Conservation Commission. It was the sense of the members present that this was a matter for the members of the two committees to determine.

State Library—Amos Butler reported that during the year, 420 items belonging to the Academy were catalogued. Foreign exchanges

are behind, but are coming slowly. Due to the high cost of materials and labor, much material is still on the shelves unbound. It was shown that members of the Academy do not use the exchanges very much. The Librarian is very anxious to have the members of the Academy use not only its own publications, but also the general library. Material can be sent to one at his home. The Librarian would be very pleased to receive suggestions from the members of the Academy about books to be purchased for their use. This is done regularly by individuals and colleges, and may as well be done by members of the Academy.

Distribution of Proceedings—Chairman Hess reported that the 1919 and 1920 Proceedings were distributed during October.

Membership Committee—H. F. Dietz reported that he had 54 names to propose at the meeting tomorrow. He suggested that the membership of this committee should be increased so that there will be one member residing at each university and college in the State, together with three members from Indianapolis.

Publication of Proceedings—Editor Payne, 1919 Proceedings, called attention to the fact that there was a deficit in the treasury due to the fact that the state printers did not take into account the cost of preparing cuts. After discussing the difficulties of editing, both from the point of view of the printers and the authors, he advised that hereafter the term of office of editor be for more than one year. He also advised that the Proceedings be cut down so that free copies of reprints can be furnished authors.

Editor Breeze, 1920 Proceedings, spoke of his difficulties as editor, chiefly among them being the lack of co-operation on the part of the state printers.

In view of the previous discussion, it was moved and carried that when the editor is in doubt about the printing of any manuscript, he be instructed to submit the paper to three members who are experts in that field, and then follow their advice.

On motion, the last two editors were appointed to draw up a set of rules for the use of authors in the preparation of manuscripts.

A letter from the Fort Wayne Printing Company was read in defense of the high cost of printing the Proceedings. Estimates were presented by President Enders from the Lafayette Printing Company for the 1919 and 1920 Proceedings, and in each instance these estimates were higher than that charged by the Fort Wayne Printing Company.

Amos Butler urged that editors consult Col. Healey concerning their editing problems. He stated that the wide experience of Col. Healey would be a help to any editor.

Treasurer—

Balance on hand December 1, 1920	$541 67
Dues collected during the year	354 00
Total	$895 67
Total expenditures	596 51
Balance in the treasury	$299 16

Auditor E. B. Williamson reported on the accuracy of the treasurer's report. On motion, the treasurer is authorized to transfer from the treasury to the trustees of the Research Endowment Fund, the sum of $100.

Relation of the Academy to the State—Robert W. McBride stated that our troubles of getting money from the State are now over so far as the publication of the Proceedings is concerned. The last session of the legislature passed a bill appropriating $2,400 for the publication of the 1919 and 1920 Proceedings, which carried with it the provision for a perpetual yearly appropriation of $1,200, and it further provided that any excess remaining at the end of any year shall be carried forward for future use. Judge McBride, at the request of the Academy, wrote this bill and urged its passage.

Concerning the state flower, Robt. W. McBride announced that, at the request of the Academy, he prepared the bill requesting that the flower of the tulip tree be named the state flower. Since this bill passed the legislature, the Academy was really instrumental in naming our state flower.

On motion, the secretary was instructed to write a letter of appreciation to those members of the House and the Senate who favored and worked in behalf of the Academy appropriation bill. The following named representatives and senators were designated:

Representatives	*Senators*
J. L. Kingsbury	A. R. Baxter
J. L. Benedict	C. J. Buchanan
	J. M. Cravens
	J. F. Decker
	Estes Duncan
	C. O. Holmes
	W. Miller
	R. L. Moorehead
	R. M. Southworth
	W. M. Swain

Advisory Council—No report.

Interstate Meetings—E. B. Williamson reported that he had interviewed a large number of the most active members of the Ohio Academy at Columbus, as well as such members of the Michigan Academy. Both parties discouraged such a plan since the meetings of the different academies are very different, both in time and character of meetings. It was moved that the entire matter be dropped and the committee discharged.

Academy Foundation—Amos Butler reported that the money that was turned over to the Endowment Committee a year ago was invested in Liberty bonds. Due to increase in the value of the bonds, together with interest, the investment is now worth about $324.

On motion it was decided that a change should be made in the Constitution in order to define the term "Patron", as contemplated in the efforts to establish an endowment fund for research. The committee

recommended the following changes in the Constitution of the Academy:

Article II—Section 2.

(1) At the end of the second sentence add "OR PATRONS".

(2) After the fifth sentence insert: "ANY PERSON WHO SHALL AT ONE TIME CONTRIBUTE ONE HUNDRED DOLLARS TO THE FUNDS OF THIS ACADEMY MAY BE ELECTED PATRON, WHO SHALL BE A LIFE MEMBER OF THE ACADEMY, FREE OF DUES."

The following nominations were made to fill vacancies made by the expiration of the term of office of Robt. W. McBride and H. L. Bruner:

Bruner and Williamson for a term of three years.

McBride and Naylor for a term of four years.

Archaeological Survey—In the absence of the chairman, Amos Butler announced that the committee had been working with the geological survey. A folder had been prepared which was now ready for distribution for the purpose of gathering information of an archaeological and historical nature.

Nomination of Fellows—No report.

Spring Meeting—The secretary read the names of three places which were suggested at the last Spring meeting. No action was taken, it being decided best to leave the matter with the program committee.

New Business—On motion, the secretary was requested to ask Judge Robt. W. McBride for a bill of his expenses in connection with bringing about the passage of the last appropriation bill.

Harry F. Dietz discussed the advisability of preparing an Index Number to all the past issues of the Proceedings. John S. Wright stated that such a number was prepared about 1900 for all previous issues, but he did not think that it was as inclusive as it should be, in that it did not include species names.

On motion, the president was instructed to appoint a Special Committee on Indexing the Proceedings of the Academy. The following committee was appointed:

Harry F. Dietz.

John S. Wright.

W. A. Cogshall requested the privilege of reading a paper by title at the meeting tomorrow, the title being "The Location of the Center of Population of the United States". The request was granted.

Adjourned 10:00 p. m.

GENERAL SESSION.

9:00 a. m., Room 200, Claypool Hotel, December 2, 1921.

Business Session.

The session was called to order by President Enders. Attendance 70. The minutes of the Executive Committee were read and approved.

The Membership Committee proposed the following named persons for membership. On motion, they were duly elected:

Adams, James Edward, 419 W. Wood St., West Lafayette.

Addington, Archie, 801 Atwater Ave., Bloomington.

Armington, J. H., Weather Bureau, Indianapolis.
Blind, Miss Charline, West Lafayette.
Boewer, P. Henry, 116 N. Ellsworth St., Lafayette.
Cain, Stanley A., 30 N. Holmes St., Indianapolis.
Campbell, Arthur, Muncie.
Campbell, Marion S., 29 N. Hawthorne Lane, Indianapolis.
Cleveland, Clarence R., 6 S. Twenty-sixth St., Lafayette.
Coggeshall, Lowell, Zoological Department, Bloomington.
Cottman, Evans W., Lanier Place, Madison.
Crozier, Alice M., 312 Kenmore Rd., Indianapolis.
Davis, Hugh L., 423 Vine St., West Lafayette.
Davis, Ward, Fortville.
DeForest, Howard, Delaware and Walnut Sts., Indianapolis.
Deuker, Henry W., Jr., Y. M. C. A., Indianapolis.
Elkin, Sarah K., 612 Harvey Ave., West Lafayette.
Franklin, Fred F., West Lafayette.
Fraze, James W., 808 W. Williams St., Kendallville.
Gayle, Joseph L., 8 Reifers Apts., Lafayette.
Guernsey, E. Y., 1421 O St., Bedford.
Hansen, Albert A., Agricultural Experiment Station, Lafayette.
Hassenzahl, Elizabeth, 424 Vine St., West Lafayette.
Howick, Howard, Indiana State Normal, Muncie.
James, Charles M., 443 Wood St., West Lafayette.
Jensen, Howard E., 360 Downey Ave., Indianapolis.
Kendrick, James B., Agricultural Experiment Station, West Lafayette.
Larrimer, Walter H., Box 95, West Lafayette.
Mackell, James F., Indiana State Normal, Terre Haute.
McAvoy, Miss Blanche, Muncie.
McDonald, Deloris, 526 E. Fifth St., Bloomington.
McEachron, Karl B., 336 Lutz Ave., West Lafayette.
McGavran, Edward, Downey Ave., Indianapolis.
Mellon, Melvin G., 403 Russell St., West Lafayette.
Moore, Kenneth W., 125 Downey Ave., Indianapolis.
Niles, Edward H., 4450 Guilford Ave., Indianapolis.
Olive, Edgar W., 721 E. Forty-sixth St., Indianapolis.
Painter, Henry R., Box 95, West Lafayette.
Pearson, George B., Box 95, West Lafayette.
Pollard, Cash B., 419 W. Wood St., Lafayette.
Rabb, Albert L., 1354 Lemcke Annex, Indianapolis.
Reinhart, Herbert F., State Board of Health, Indianapolis.
Smith, Ernest R., 711 E. Seminary St., Greencastle.
Stacy, Allan R., 1555 Ashland Ave., Indianapolis.
Stuppy, George W., 1102 N. Sixteenth St., Lafayette.
Telfer, Margaret, 403 W. Fifth St., Bloomington.
Thompson, Miss Dorothy, Dayton.
Twitty, Victor C., 4922 Central Ave., Indianapolis.
Wilhite, Miss Ida B., Butler College, Indianapolis.
Wilkinson, P. D., Indiana State Normal, Terre Haute.
Williamson, Jesse H., Bluffton.

Wilson, Geo. B., 330 Fowler St., West Lafayette.

Witmer, Samuel W., 1405 Ninth St., Goshen.

Zerfas, Leon G., Indiana University Medical School, Indianapolis.

The following members were elected to the Research Committee of the Academy Foundation:

J. P. Naylor for a term of four years.

E. B. Williamson for a term of three years.

On motion, it was decided to reassemble thirty volumes of the 1920 Proceedings and distribute the parts as author's separates.

F. B. Wynn, on behalf of the Committee on Archaeological Survey, stated that blueprint maps had been prepared of about every county in the State, and that these would be mailed to members in their respective counties. He stated that it was the intention of the committee to ask the co-operation of members of different universities in making reports of their respective localities.

Regarding the present deficit in the printing funds of the Academy, it was the sense of the members present that the legislature should not be approached for another appropriation, but that editors should be very careful in the future not to let the printers exceed the $1,200 appropriation. On motion, it was decided that the past two editors should confer with the state printers and the state auditor, and settle the matter in the best possible way.

The proposed amendment to the Constitution of the Academy was read at this time.

Adjourned 10:00 a. m.

GENERAL SESSION.

The papers of the General Session were now taken up in their regular order. At the close of the reading of these papers, the Academy adjourned for luncheon.

1:30 P. M. BUSINESS MEETING.

J. J. Davis, as chairman of the committee which was named to investigate the resolution presented by Arthur McDonals of Washington, D. C., consolidating the science bureaus of the various government organizations under the jurisdiction of the Board of Regents of the Smithsonian Institution, begs to report as follows:

> "After carefully studying the plan advocated, as printed in the Congressional Record of the first session of the 67th Congress, Vol. 61, No. 139, October 26, 1921, the committee recommends that the plan not be indorsed, because in our opinion it is not only ill-advised and unnecessary, but undesirable and impracticable."

J. J. Davis.
J. P. Naylor.
D. M. Mottier.

The proposed amendments to the Constitution of the Academy were read and on motion they were adopted.

A resolution was passed that the Academy express its hearty appreciation to the management of the Claypool Hotel for supplying rooms and other accommodations for our meetings.

Committee of Nominations.

The chairman of the committee read the report, as follows:

Officers for 1922.

President—F. M. Andrews, Bloomington, Ind.
Vice-President—C. A. Behrens, West Lafayette, Ind.
Secretary—W. N. Hess, Greencastle, Ind.
Assistant Secretary—H. F. Dietz, State House, Indianapolis, Ind.
Treasurer—W. M. Blanchard, Greencastle, Ind.
Editor—F. Payne, Bloomington, Ind.
Press Secretary—F. B. Wade, Shortridge High School, Indianapolis, Ind.

On motion, the above named officers were elected.

Mr. Lieber called attention of the Academy to the very poor facilities of the present state museum. Discussion resulted in a resolution being passed by the Academy as follows:

Resolved, That it is the sense of the Indiana Academy of Science that a portion of the proposed Soldiers' Memorial should be devoted to the State Museum.

F. B. Wynn suggested that committees from the different science and historical organizations be selected to solicit the Memorial Committee for this purpose.

Adjourned for Sectional Meetings at 2:00 p. m., Biological Section to the Assembly Room; Physical Section to Room 200.

Fifty-seven members participated in the Academy dinner at 6:00 p. m. At the close of the dinner, the Academy met in the Assembly Room for a general session open to the citizens of Indianapolis. The following lectures were presented:

"Winthrop Ellsworth Stone." An appreciation, by Stanley Coulter.

"Topographic Development of Western South America as Indicated by the Fresh Water Fishes." C. H. Eigenmann.

"Some Observational Results Secured at the Lowell Observatory." V. M. Slipher, Lowell Observatory, Flagstaff, Arizona.

At 11:00 p. m. the 37th Session of the Indiana Academy of Science closed.

H. E. Enders, President.

Walter N. Hess, Secretary.

PROGRAM OF THE THIRTY-SEVENTH ANNUAL MEETING

OF

THE INDIANA ACADEMY OF SCIENCE

HELD AT

THE CLAYPOOL HOTEL, INDIANAPOLIS

Thursday and Friday, December 1 and 2, 1921

OFFICERS.

HOWARD E. ENDERS, West Lafayette........................President
F. M. ANDREWS, Bloomington........................Vice-President
W. N. HESS, Greencastle..................................Secretary
H. F. DIETZ, Indianapolis........................Assistant Secretary
F. B. WADE, Indianapolis............................Press Secretary
WM. M. BLANCHARD, Greencastle.........................Treasurer
J. F. BREEZE, Muncie.......................................Editor

PROGRAM COMMITTEE.

R. C. FRIESNER. WM. M. BLANCHARD.
F. B. WYNN.

OUTLINE OF PROGRAM.

THURSDAY, DECEMBER 1.

8:00 p. m. Executive Committee Meeting.

FRIDAY, DECEMBER 2.

9:00- 9:30 a. m. Business Meeting, Parlor "B."
9:30-12:00 a. m. General Session, Parlor "B."
1:30- 2:00 p. m. Business Meeting, Assembly Room.
2:00- 6:00 p. m. Sectional Meetings: Biological Sciences in Assembly Room, Physical Sciences in Parlor "B."
6:00- 8:30 p. m. Annual Academy Dinner, in Florentine Room. Dean Stanley Coulter, of Purdue University, will act as toastmaster. Members who expect to be present at this dinner will please mail the enclosed card at once, in order that plates may be reserved.
8:00 p. m. General Session, in Assembly Room.

GENERAL SESSION.

PARLOR "B," FRIDAY, 9:30-12:00 A. M.

1. Prehistoric Indiana Archaeology; Stone-Age Occupation, Geographically. 12 minutes. Stephen Francis Balcom, Indianapolis.

2. Plans for Teaching Science in Evansville College. 10 minutes. A. J. Bigney, Evansville College.
3. The Popping of Corn. 20 minutes. Paul Weatherwax, Indiana University.
4. Winthrop Ellsworth Stone: An Appreciation. 10 minutes. Stanley Coulter, Purdue University.
5. Alfred Monroe Kenyon: In Memoriam. 10 minutes. Thomas E. Mason and W. A. Zehring, Purdue University.
6. William Watson Woollen: In Memoriam. 10 minutes. Amos W. Butler, Indianapolis.
7. Treatment of Rhus Poisoning. 5 minutes. O. P. Terry, Purdue University.
8. A Moon Rainbow. 10 minutes. Albert B. Reagan, Indian Schools, Kayenta, Ariz.
9. The Aurora Borealis Seen at Kayenta, Ariz., May 14, 1921. 10 minutes. Albert B. Reagan.
10. Songs and Medicinal Receipts of George Farmer Ne-ba-day-ke-shi-go-kay. 10 minutes. Albert B. Reagan.
11. The Origin of the Pacific Slope Fishes of South America. 20 minutes. C. H. Eigenmann, Indiana University.

SECTIONAL PROGRAM.

FRIDAY, 2:00-6:00 P. M.

PHYSICAL SCIENCES—PARLOR "B."

Physics and Chemistry.

12. Decrement Measurements. 10 minutes. R. R. Ramsey, Indiana University.
13. Effects of Heat on the Enzyme Peroxidase. 10 minutes. George Spitzer and Naomi C. Taylor, Purdue University.
14. Chemical Structure of High Protein Corn. 10 minutes. R. H. Carr and M. F. Showalter, Purdue University.
15. Ozone in Ventilation: Revivication of Mice. Lantern. 5 minutes. F. O. Anderegg, Purdue University.
16. A Chemical Study of the High Frequency Corona Discharge. Lantern. 10 minutes. F. O. Anderegg.
17. Ozone as a Bleaching Agent for Steam Laundries. 10 minutes. F. O. Anderegg and R. H. Carr, Purdue University.
18. The Simultaneous Electro-Deposition of Lead and Lead Peroxide. Lantern. 10 minutes. M. G. Mellon and H. F. Reinhard, Purdue University.
19. Some Experiments on the Determination of Lead in Lead Amalgams. 5 minutes. M. G. Mellon and H. F. Reinhard.
20. Chlorinating Mixed Silver Halides in Gooch Crucibles. 5 minutes. M. G. Mellon and J. C. Siegesmund, Purdue University.
21. Fertilizer Treatment as Affecting Nitrate Formation. 10 minutes. I. L. Baldwin, W. E. Walters, and F. K. Schmidt, Purdue University.

22. Crop Rotation as Affecting Nitrate Formation. 10 minutes. I. L. Baldwin, U. L. Coble, and J. W. Chamberlain, Purdue University.

Geology and Geography.

23. Archaic Investigations, 1921. 5 minutes. W. N. Logan, Indiana University.
24. The Structural Conditions in the Eastern Indiana Oil Field. 10 minutes. W. N. Logan.
25. A Subterranean Cut-off. 5 minutes. Clyde A. Malott, Indiana University.
26. Lost River and Its Subterranean Drainage. 15 minutes. Clyde A. Malott.
27. The Decline of Lakes near Laporte, Ind. 15 minutes. W. M. Tucker, Indiana University.
28. A Concretionary Zone in the Knobstone. Lantern. 10 minutes. W. M. Tucker.

BIOLOGICAL SCIENCES—ASSEMBLY ROOM.

Botany (Including Bacteriology)

29. Saprolegnia. 5 minutes. F. M. Andrews, Indiana University.
30. Some Abnormal Forms of Spirogyra. 5 minutes. F. M. Andrews.
31. Trillium Nivale. 5 minutes. F. M. Andrews.
32. The Sporangium of Vaucharia. 5 minutes. F. M. Andrews.
33. The Reclamation of Soil by Fungi. 10 minutes. F. M. Andrews.
34. A Pocket Dissecting-scope. 5 minutes. Elmer G. Campbell, Purdue University.
35. A Panorama of Stone Mountain and Its Vegetation. Lantern. 15 minutes. Elmer G. Campbell.
36. Preparation and Use of Collodion Sacs in Exalting Micro-organisms. Charles A. Behrens, Purdue University.
37. Red Cedar in Indiana. 10 minutes. Stanley Coulter, Purdue University.
38. Plants New to Indiana. X. 3 minutes. Charles C. Deam, State Forester, Bluffton.
39. Indiana Fungi. VI. 5 minutes. J. M. Van Hook, Indiana University.
40. Evidences of the Seed Carriage of Certain Euphorbia Rusts. 5 minutes. E. B. Mains, Purdue Agricultural Experiment Station.
41. Observations Concerning *Puccinia Pattersoniana.* 5 minutes. E. B. Mains.
42. The Growth of Tree Twigs. 10 minutes. C. A. Ludwig, Clemson College, South Carolina.
43. Indiana Plant Diseases. 1921. 10 minutes. Max W. Gardner, Purdue Agricultural Experiment Station.
44. On the Endogenous Formation of Flowers. 5 minutes. T. G. Yuncker, DePauw University.
45. Development of Sporogenous Tissue in the Foot of the Sporophyte of *Porella platyphylla* (L) Lindb. 5 minutes. Flora Anderson, Indiana University.

46. Unusual Stipules of *Acer nigrum* Michx. 10 minutes. Flora Anderson.
47. Plants of White County. IV. By title. Louis Heimlich, Purdue University.
48. Peloria in Linaria. By title. Louis Heimlich.
49. Additions to the List of Indiana Mosses. 2 minutes. T. G. Yuncker, DePauw University.
50. Additions to the Fungus Flora of Indiana. 5 minutes. H. S. Jackson, Purdue Agricultural Experiment Station.
51. Methods in Plant Nutrition Studies. 15 minutes. H. A. Noyes, J. H. Martsolf, and H. T. King, Mellon Institute of Industrial Research, Pittsburgh, Pa.
52. Bacterial Indices. 15 minutes. H. A. Noyes, Mellon Institute of Industrial Research, Pittsburgh, Pa.
53. The Flora of the Olympic Peninsula, Washington. 10 minutes. Albert B. Reagan, Indian Schools, Kayenta, Ariz.
54. Annotated Bibliography of Mycological and Phytopathological Literature for Indiana. 5 minutes. H. S. Jackson, Purdue Agricultural Experiment Station.

Zoology.

55. Light Reactions and Photoreceptors of Annelida. 8 minutes. Walter N. Hess, DePauw University.
56. Preliminary Note on Hydrogen Ions in Solution in Ponds. 5 minutes. Will Scott, Indiana University.
57. Life History of *Hyallela Knickerbockerii.* 10 minutes. Dona Gaylor, Indiana University.
58. Food of the Fishes of Winona Lake. 10 minutes. Willis DeRyke, Indiana University.
59. Army Worm Control Through County Organization. 5 minutes. Walter H. Larrimer, U. S. Entomological Laboratory, West Lafayette, Ind.
60. A Preliminary Report of the Hog Lung-worms. 10 minutes. George Zebrowski, Purdue University.
61. The Effect of Temperature upon an Eyeless Race of *Drosophila hydei* Sturtevant. By title. Roscoe R. Hyde, Johns Hopkins University, Baltimore, Md.

GENERAL PROGRAM.

FRIDAY, 8:00 P. M., ASSEMBLY ROOM.

62. Address of the Retiring President, The Problems of Life among Parasitic Animals. Howard E. Enders, Purdue University.

ADDITIONAL TITLES.

(The following titles were received too late to be included in the main printed program. They will be read at the times and places designated below.)

PHYSICS AND CHEMISTRY, FRIDAY 2:00-6:00, PARLOR "B."

63. Fakers in Science. 10 minutes. E. G. Mahin, Purdue University.
64. The Integrating Power of Photographic Plates. 5 minutes. Arthur L. Foley, Waterman Institute for Research, Indiana University.

PHYSICS AND CHEMISTRY, FRIDAY, 2:00-6:00, PARLOR "B."

65. Acyl Derivatives of O-Aminophenol. 10 minutes. R. E. Nelson and H. L. Davis, Purdue University.
66. Beta Sulphur Trioxide. 5 minutes. E. G. Mahin, Purdue University.
67. A Study of Explosions. Lantern. 8 minutes. John B. Dutcher, Indiana University.
68. Some Diffraction Patterns. Lantern. 5 minutes. John B. Dutcher.
69. The Dependence Between Sound Wave Reflection and Frequency. Lantern. 5 minutes. Arthur L. Foley, Waterman Institute for Research, Indiana University.
70. The Amplifying Effect of Horns and Other Sound Receivers. Lantern. 5 minutes. Arthur L. Foley.
71. The Effect of Horns on the Distribution of Sound Energy about a Sounding Body. 10 minutes. Arthur L. Foley.
72. The Actinic Quality of the Electric Spark. 5 minutes. Arthur L. Foley.
73. The Effect of Ultra-Violet Light and X-Rays on the Stability of Matter. Lantern. 10 minutes. Arthur L. Foley.

GEOLOGY AND GEOGRAPHY, FRIDAY, 2:00-6:00, PARLOR "B."

74. A Field Trip Through the Eastern States. 15 minutes. Fred J. Breeze, Indiana State Normal School, Eastern Division.
75. The Hewitt Oil Field, Carter County, Oklahoma. By title. Louis Roark, Okmulgee, Okla.

BOTANY, FRIDAY, 2:00-6:00, ASSEMBLY ROOM.

76. The Toll of Weeds in Indiana. 10 minutes. Albert A. Hansen, Purdue Agricultural Experiment Station.

ZOOLOGY, FRIDAY, 2:00-6:00, ASSEMBLY ROOM.

77. A National Insect Pest Survey and Its Relation to Indiana. 15 minutes. John J. Davis, Purdue University.
78. An Insect Pest Survey for Indiana. 10 minutes. John J. Davis.

All meetings at which papers are read are open to the public. Visitors are especially welcome at the general program to be given Friday at 8:00 p. m. in the Assembly Room.

The program committee will appreciate suggestions with regard to the meetings, especially with regard to the coming spring meeting.

If you have not paid your dues, they should be given to the treasurer during the meetings.

HAVE YOU RESERVED YOUR PLATE FOR THE BANQUET?

SUPPLEMENT TO THIRTY-SEVENTH ANNUAL PROGRAM.

The following titles were received after the printed programs were in the mails. They will be read at the times and places listed below:

General Program, Friday, 9:30-12:00, Parlor "B."

79. Report of the Second International Eugenics Congress, New York, September, 1921. 10 minutes. Arthur H. Estabrook, Indianapolis.

Chemistry, Friday, 2:00-6:00, Parlor "B."

80. Some Characteristics of a Siemens Ozonizer. Lantern. 10 minutes. Karl B. McEachron, Purdue University.

Botany, Friday, 2:00-6:00, Assembly Room.

81. Notes on Indiana Plant Diseases. By title. Harold E. Turley, Department of Conservation, State House, Indianapolis.

Zoology, Friday, 2:00-6:00, Assembly Room.

82. Distribution of the Mussels of Winona Lake. 10 minutes. William Ray Allen, Municipal University, Akron, Ohio.
83. A New Mutation in the Mouse, *Mus musculus*. 5 minutes. Horace W. Feldman, University of Illinois.

General Program, Friday, 8:00-10:00, Assembly Room.

84. Topographic Development of Western South America as Indicated by the Freshwater Fishes. C. H. Eigenmann, Indiana University.

William Watson Woollen.

Let us stop for a moment. I would pay a tribute of appreciation to William Watson Woollen, the oldest of our members.

Our good friend has gone. For some twenty-five years I have had the privilege of knowing him. He was a faithful member of this Academy, regular in attendance upon its meetings, faithful in his duties, enthusiastic in our cause. He was one of the charter members of the Indiana Audubon Society, in which he has filled almost every office. He was the founder of the Indiana Nature Study Club and from its beginning its most enthusiastic and most distinguished member.

He came of pioneer stock, inherited a strong constitution and carried always the spirit of the pioneers. He loved the things of the early days. The trees and woods and their inhabitants were all his friends. He saw with regret the vanishing of our wild life—the wild flowers, the primeval forest and the birds. He believed not only in natural things but also in the simple life. He lived close to nature, a free, happy life, close to the things of God. He was an optimist—a natural thing with one who continually communed with nature. His bit of forest land, in which he had intense interest, he called "Buzzard's Roost." Later he gave it the name, "Woollen's Garden of Birds and Botany." It attracted much attention both at home and abroad. On one occasion I recall how he showed us with much pride an invitation to attend a dinner at Shaw's Garden in St. Louis, and speak on the subject so near his heart. Sometime since he presented it to the city of Indianapolis, to be preserved forever as a natural park. He studied much and wrote for the daily press and for other publications. He published an interesting volume entitled "Birds of Buzzard's Roost," an autograph copy of which I have. It was dedicated to the children and the birds. His contributions were popular in character and helpful to a wide circle of readers.

He is dead—yet he speaks. He speaks in all the good works he did; in all the manifestations of his unselfish spirit, in the lives of little children whose minds were led into a greater appreciation of the works of the Creator and the rights of His creatures. He was interested in children. The children were interested in him. He easily aroused their interest and gained their confidence. He taught them to be humane, to love the birds, the flowers and the interesting things of nature. The seed he planted is growing and will blossom and fruit. It will go on indefinitely reproducing in the minds of other children the lessons he strove to teach. His message to the children was like a pebble dropped into the water. The ripples it started will spread wider and wider until their influence will reach so far that it can not now be predicted. How far-reaching are the results of such devoted and unselfish effort!

To him, the nature lover, the inspiration to many, the teacher of children, our thoughts turn at this hour. The cause he served has lost a noble advocate, our city and State a useful citizen. Our memories of his service and his helpful friendship we would keep green. With bowed heads and sorrowing hearts we pause to offer a tribute of respect to him.

Amos W. Butler.

WINTHROP ELLSWORTH STONE.

Born—Chesterfield, N. H., June 12, 1862.
B. S.—Massachusetts Agricultural College, 1882.
B. S.—Boston University, 1886.
Ph. D.—Göttingen, 1888.
LL. D.—Michigan Agricultural College, 1907.
Assistant Chemist, Massachusetts Agricultural Experiment Station, 1884-1886.
Student at Göttingen, 1886-1888.
Chemist, Tennessee Agricultural Experiment Station, 1888-1889.
Professor of Chemistry, Purdue University, 1889-1900.
Vice-President and Professor of Chemistry, Purdue University, 1892-1900.
President, Purdue University, 1900 to July 17, 1921.

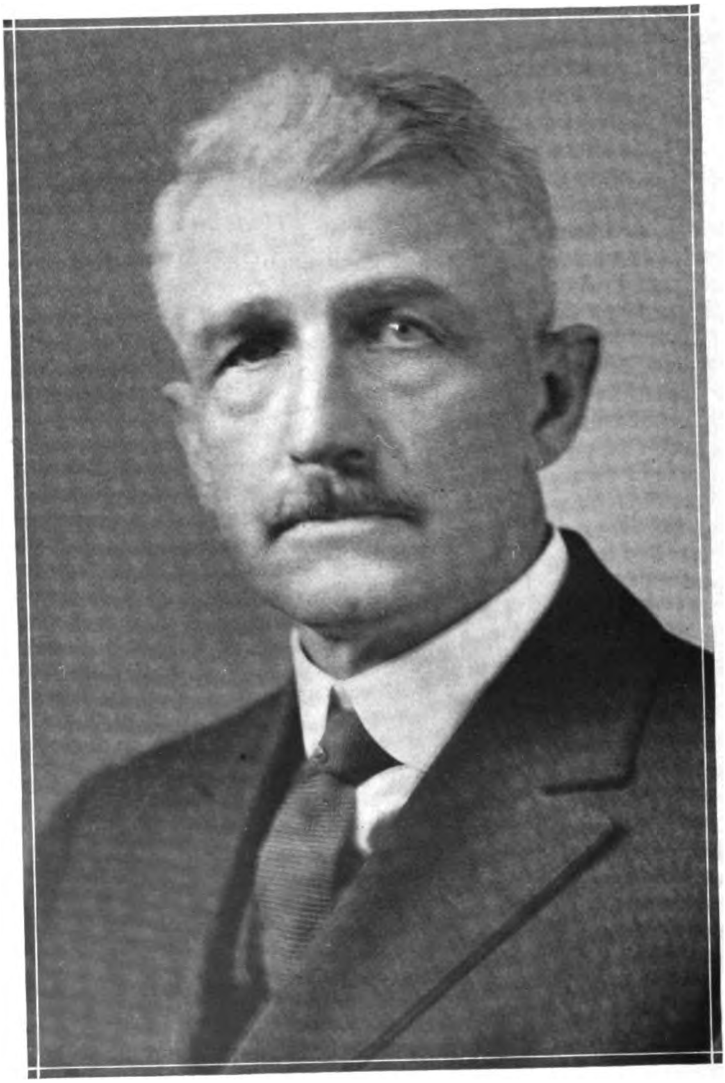
These are the significant dates in a life of unremitting toil and high achievements—a life that meant much to the State and to the cause of education. They are more than mere dates, for they tell of heredity, of natural aptitudes, of training, of ambitions and of achievements. The great, steady sweep of such a life can only be realized by those who through the intimacies of daily association have been able to separate its incidental surface features from its underlying fundamental and basic principles.

To his New England ancestry we can attribute the Pilgrim element in his blood. He had the Pilgrim faith in Almighty God and the Pilgrim faith in his own high mission. In the courage born of these faiths he did his work and lived his life. To the accomplishment of the high purpose to which he felt he was called he devoted every power of body and mind and soul, and no pressure of persuasion or criticism could turn him from the path he had marked out, which was to him the path of duty.

He had also in a very large measure the Pilgrim's instinctive sense of fairness and justice. In all of the years of my association with President Stone, I never heard his fairness questioned. We might feel at times that there was a little too much of the New England granite in him, but we never questioned the absolute fairness and justice of his decisions.

In spite of his manifold duties President Stone was always easily accessible. No member of the University force ever failed to receive a patient and sympathetic hearing. He was indeed essentially democratic; he hedged himself about with no dignities; he was a man among men in the University life, but, *facile princeps.*

It is scarcely necessary to speak of his fine integrity. It pervaded his every act. It was a part of his very being. His acts were as direct and clean cut as his thoughts and words. This ingrained honesty made him a man both positive and aggressive. He never avoided an issue, nor feared a fight for what seemed to him to be right. He was noth-



ing of an opportunist, very little of a politician. He fought in the open and won his battles not by indirection but because of the righteousness of his cause.

He was finely sensitive to the moralities of life and was persistent in efforts to improve the moral conditions surrounding the thousands of students under his direction and for whose welfare he was in a large measure held responsible. He felt the obligations of citizenship as few of us do, and whether called for duty by city, State or nation gave loyal and effective service. If the purpose of our Universities is to develop a trained citizenship, then President Stone was at once a matchless leader and a brilliant example.

If we attempt to measure him by those things which appealed to him in his moments of leisure and relaxation we may perhaps gain a truer conception of his fine and attractive personality. He was an intense lover of music, losing no opportunity of hearing great artists. His was a taste trained to the appreciation of the best both in theme and interpretation. He played no instrument, he did not sing, but he found in music that which answered needs of mind and heart and soul. He loved books, and here again his taste was of the best. It needed but a casual glance at his library to see how wide-ranging were his interests and what his books meant to him. But above all he loved nature. He loved flowers and trees and knew them; he loved birds and animals and understood their ways; he loved the outdoor world and revelled in its beauties, whether it was the serene and quiet beauty of the meadows and lakes and rivers, or the majestic, ineffable grandeur and beauty of glacier-clad mountains. One can readily understand what such a passion for nature meant to the tired man, not merely in satisfying his love for beauty, but as an actual recreation.

If he had to leave us, there is something of comfort in the thought that in full vigor of body and mind, doing that which called him so compellingly, having won the summit he had sought to conquer, he entered upon the "*great adventure.*"

President Stone became a member of the Academy in 1889, when he took the chair of Chemistry at Purdue University. In the earlier years of his membership he was regular in his attendance upon both the winter and spring meetings. As administrative duties crowded upon him he found himself unable to attend as frequently as he desired. In spite of this he never lost interest in the Academy, attending its sessions when it was possible for him to do so, and each year urging members of the faculty to an active participation in its affairs. In his early years he published quite largely, as will be seen by the following bibliography, for the compilation and use of which I am indebted to Dr. P. N. Evans:

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STANLEY COULTER, Purdue University.

Alfred Monroe Kenyon.

Alfred Monroe Kenyon was born December 10, 1869, on a farm near Medina, Ohio, not far distant from Cleveland. His boyhood life was spent in a humble but very comfortable country home. He attended the district school near by and later the high school at Medina. After graduating from the high school he taught for two or three years in the country schools. In the fall of 1890 he entered Hiram College and four years later was graduated with highest honors, receiving the A. B. degree. The following two years were spent as principal of the high school at Wellington, Ohio. In 1896-97 he was a graduate student in Western Reserve University and a teacher of freshman mathematics in Case School of Applied Science. The next year he entered Harvard University as a graduate student and university scholar and received his A. M. degree from that institution in the spring of 1898.

Professor Kenyon came to Purdue University as an instructor in mathematics in 1898. On account of the efficient service he rendered the University his promotion was rapid. In 1900 he was made Registrar, an office requiring about an hour a day at that time. In 1901 he was promoted to be Assistant Professor and in 1908 to be Professor of Mathematics, giving up his duties as Registrar. In this year he succeeded Professor C. A. Waldo as head of the department of mathematics, which position he occupied until his death.

Professor Kenyon was called to his former home by the death of his mother. On the return to Lafayette he was taken suddenly ill on an interurban car which he left at Ashland, Ohio, to seek medical aid. His condition became worse and he died within an hour after leaving the car. This occurred on July 27, 1921. The unexpected death of Professor Kenyon coming in the same week with the news of the loss of President Stone added greatly to the shock of the university community. Professor Kenyon was buried at Lafayette on July 29, 1921.

In 1897 Professor Kenyon was married to Grace Greenwood Finch. His wife and three children survive.

The productive part of Professor Kenyon's life was spent at Purdue University and it might properly be said that he gave his life for the University. He had a great part in shaping the policies and in moulding the character of the institution. His logical analysis and fair judgment on all problems of administration were recognized by all. He served frequently on important committees of the faculty and at the time of his death was a member of the executive committee. He was most successful as head of the department of mathematics. He laid down no rules of conduct and did not insist on special methods of teaching or of class management, but by a kind brotherly friendship inspired each member of his department to do his best. He always revealed a genuine human interest in the man as well as in the instructor. This

is the thing, that those of us, who knew him best, will miss most in his loss.

Professor Kenyon was a very successful teacher. He was thoroughly prepared for his work and was always able to present his subject in a clear and vigorous manner. He never lost the student's viewpoint and spent much time in working out in great detail problems which interested his students. Professor Kenyon's influence among students was not limited to the class room. He was ever ready to respond to any demand which in his opinion meant an uplift to the student life. He served as a member of the executive committee of the Y. M. C. A. and as financial secretary of the Purdue Union. Professor Kenyon lived as a man among men, he was no recluse. He took a keen and active interest in all matters of church and community.

Whatever ability as an investigator and research worker in mathematics Professor Kenyon may have had was largely covered up by administrative duties. He never lost interest in mathematics but by constant study, by attendance at mathematical meetings, by contact with mathematicians, kept in touch with modern mathematical problems. At intervals he found time to do short pieces of original work, some of which have been published in the Proceedings of this Academy, in the American Mathematical Monthly and elsewhere. He was joint author of texts on trigonometry and of a text for mathematics for students of science and agriculture.

Professor Kenyon was a member of this Academy, elected a Fellow in 1914; of the American Mathematical Society; of the Mathematical Association of America; of the Society for the Promotion of Engineering Education; of the American Association of University Professors; and of the honorary scientific society, Sigma Xi.

T. E. Mason and W. A. Zehring, Purdue University.

President's Address.

THE PROBLEMS OF LIFE AMONG PARASITIC ANIMALS.

Howard E. Enders.

The development of parasitology as a special phase of zoology has been made possible through a recognition of its economic applications in agriculture, horticulture, veterinary medicine and public health. The applications in medicine and public health help to re-establish the close relationship to the science of medicine from which zoology originally developed into the importance of a separate science.

Need for the further development of the field of parasitology was thoroughly emphasized in the recent war, through the work accomplished by the parasitologists of the Sanitary Corps in eradication of the lice, which became active agents in the spread of typhus and trench fevers that levied a heavy toll throughout all of Serbia and more or less elsewhere. Before the war few colleges offered courses in this work but with the return of men to the educational duties new courses were undertaken and the older courses were given new life and renewed activities in a field in which so much remains to be investigated.

A generation or two ago, when the presence of amiable flies about the table was a token of the hospitality and general kindliness of the hostess, the louse and the flea and other more or less personal attendants were regarded at most only as petty annoyances. Most of these forms are now regarded as parasites. In its original use the term "parasite" was employed to describe those who sat about the tables of the rich of ancient Greece, by virtue of their fawning and flattery. It does not require a wide stretch of the imagination to understand how a similar relation was ascribed to the animals which lived upon other animals and there maintained a thievish existence at the expense of the host. How they came into being, or how they came to be where they were was as readily accounted for as was the origin of Topsy, in "Uncle Tom's Cabin", and each had as real a purpose in life as was expressed by "David Harum" of the fleas: "A reasonable amount of fleas is good for a dog; it keeps him from brooding over being a dog."

The idea that life could spring suddenly into existence made it as readily possible to account for the origin of any parasite within or upon a host, as for the host itself. The belief in the spontaneous origin of parasites and "other vermin" from filth or other "formative materials", was so firmly held that formulas were given for the production of certain forms of life, and to doubt it was to question reason and truth.

Development within the field of biology in a period possibly only a little longer than the lifetime of the oldest person here, has been made possible through the epoch-making discovery of protoplasm as the physical basis of life; the formulation of the cell-theory; the exposition of the theory of evolution of plants and animals; the development of the

science of bacteriology and with it the proofs that life does not arise spontaneously, and finally the formulation of the modern theories of heredity. Thus the old theories have been proven untenable so that now the period from generation to generation represents a definite sequence or a series of steps in a definite life-cycle.

The term "parasite", now one of the common terms in biological literature, is so difficult to define that it seems almost impossible to have two workers agree without a series of qualifications of its meaning. Megnin has defined parasites as those which live at the expense of others which are living. The definition recognizes a symbiotic relationship between the parasite and its host, upon which or within which it may maintain its existence for a shorter or longer time, possibly only for an occasional visit or for the whole of a lifetime.

Whatever the relationship to its host the parasite, if it is successful, lives and grows and in turn reproduces its kind, but to do so it must solve the problems of life. These may be serious ones, and the hazards of gaining a foothold and maintaining itself and reproducing are out of all proportion to those with which man, his domesticated animals and most other free-living forms must cope.

The parasite may be a permanent or a temporary resident upon the outside of a host that mingles little or much with others of its kind; it may live within the digestive tract or kidneys, liver, lungs or in the circulatory apparatus, within which it may move with more or less ease but from which escape to a new host becomes more difficult; it may live within the tissues from which escape seems even less certain, unless the host is eaten by some predaceous form, or its carcass is devoured by some scavenger.

> If it is on the outside of a host how does the parasite maintain its place or avoid dislodgment?
>
> How does it maintain itself inside the body without being strangled, if respiration is necessary?
>
> How does it maintain itself in a digestive tract in which it encounters the inhospitable digestive enzymes that act upon other substances like those of its own body?
>
> How does it perform the fundamental functions of life, as reproducing itself, etc.?
>
> If it or its young find the way to the soil or water how are the new conditions withstood?
>
> If neither it nor its eggs or the young can escape from the host, what of the future?
>
> What chance do the progeny have of securing a foothold and what difficulties do they encounter, or how do the progeny come to find a similar or suitable host?
>
> Above all, how did the particular parasite come to live as it does?

These are some of the problems that the successful parasite solves when it maintains itself and reproduces its kind.

The last of these questions, "Above all, how did the particular parasite come to live as it does?" may be considered first, in a general way, as it applies to a few of the permanent ectoparasites. From the investigations of others and from my own observations I have been able to obtain a large volume of data on various aspects presented in different states of symbiosis which have been included under the term parasitism.

To each of us—though with certain reservations—it has been a matter of common observation that the mosquito, the blood-sucking fly, or the bed-bug and flea, or a tick, may make an occasional levy for blood, but that any warm-blooded animal may serve equally well as a temporary host, only long enough to secure their fill, or until they are interrupted in the act. The length and strength of the piercing beak here seems to guarantee an ample supply of food from any warm-blooded animal whose skin is not too thick to be penetrated, so the food problem is not a difficult one. Sooner or later they lay their eggs which develop apart from the host, and in time the young of only one of these return for the food that is necessary to maintain a livelihood, and for them the food question is simple, for they share the same bed with their host. The progeny of the flea and the mosquito forage in a free environment but the ticks, numbering from two thousand to ten thousand from a single mother, crawl up stems and blades of grass and there wait. If a new, warm-blooded animal passes, or if they chance to attach themselves to a favorable host, they may gain a meal and live, but the hazards are great, and on the average there are no more ticks in one season than in another, which means that a little tick has scarcely one two-thousandth, or even one ten-thousandth of a chance of reaching maturity.

As one leafs over a series of volumes and reprints he may observe little flat-bodied, wingless book-lice that have been disturbed in their meal upon the glue of the bindings, and in them he may recognize the same characteristics of structure that occur in a host of forms that live as parasites, permanent parasites, on our domestic poultry and on our wild birds. Other relatives of these free-living book-lice are found upon the bark of trees, and in some manner they may have found their way to the bodies of the ancestors of our present-day birds. The whole organization and structure is so similar that we have good reason to conlude that the bird-lice, the Mallophaga, fifteen hundred different species, have descended from the ancestors from which the book-lice have come. The food which they now take consists of the small fragments of feathers and dead skin, instead of the glue or other animal or plant products of their free-living relatives.

The eggs of the Mallophaga are glued to the feathers, or to the hairs, for about one hundred of the fifteen hundred known species have taken up their abode on mammals, by a clasping action of the posterior end of the abdomen of the female. The young feed from birth upon hairs or feathers and free scales of skin as the parents do, and neither they nor their parents leave the body of the host except under unusual circumstances. It is only very rarely that straggling lice are found on the perches, or the roosting places on seaside rocks from which scores

of abundantly parasitized birds, such as cormorants, gulls or pelicans, have been frightened.

Normal migration from bird to bird occurs when in contact, among gregarious groups, or at mating from female to male, or *vice versa*, or to the fledgling birds at the time of brooding.

Upon the death of the host some of the lice wander off the cold body with little chance ever to become relocated within the three or four days in which they can live under the most favorable conditions. Many usually remain, but only to perish within ten days, firmly gripping feather barbules between their jaws. Those which could have subsisted upon the foods of their ancestors in a free range have long since passed away, and only these remain whose food and living conditions have been unchanged for so long a time that individuals having variable tastes have been bred out.

The Mallophaga are capable of living on certain hosts toward which they have developed a certain physiological fitness. The curious sensitiveness to differences in composition of host hair and feathers or skin and oil, etc., is so marked that those of our number who, in the course of a hunting trip, or in their collection, inadvertently became the temporary hosts of bird- and mammal-infesting mallophaga and anoplura found these parasites as eager to escape as we were to have them do so—or in the failure of which they died in a few hours. The real reasons for failure to live are not apparent and we conclude that it represents a particular physiological fitting in addition to the presence of the number, size and shape of claws and conformation of clinging devices or spine-hairs set at a particular angle to afford security of position on the body. If the species common to wild birds are transferred experimentally to guinea pigs, which ordinarily support two species of mallophaga, or to our common poultry, they are unable to maintain themselves even though the skin and hair, or the feathers, would seem to serve the same purpose, as food. It is likewise true that birds of prey do not fall heir to the parasites which were common to the birds or mammals upon which they prey, though to this there are occasional exceptions.

The progeny of permanent ectoparasites represent a closely inbred strain that is isolated biologically from the rest of the individuals comprising the species which it represents and with it go all the possibilities that are associated with the fixation of hereditary qualities. In a sense the relationship represents an environment that is comparable to island life. On such island the individuals pass a life that is monotonously alike whether the bird is aerial, terrestrial or aquatic.

Kellog, who has described hundreds of new species of mallophaga, asserts that the relative isolation plays a conspicuous rôle in the formation of species. He and other workers ascertained that closely related birds, whatever their geographical range, are the hosts of closely related mallophaga. Thus, the species, *Lipeurus baculus*, which occurs on the domesticated pigeon, has been collected from nineteen of the forty pigeon host-species that range through Europe, Asia, Africa, North America, Malaysia, Australia, Madagascar, and the Galapagos Islands, and that of the twelve species which occur on the domesticated

fowl four are commonly found on the reputed wild ancestor, the jungle fowl.

According to Kellog's well-sustained thesis we are led to the conclusion that the progeny of the present-day species of lice are the direct lineal descendants of the lice which began as parasites upon the ancestors of these birds and, in so far as identical species appear upon closely related birds, it implies an alteration of the bird without that of the parasite, while in other instances, on identical species of birds of wide geographical range, mallophaga have been found that exhibit either varietal or even specific differences. It follows, then, that phyletic relationship may be determined in some cases of doubtful relationship of host, by a close study of its wingless, permanent ectoparasites. In this connection it is of interest to recall that certain anthropoid apes harbor two of the three species of pediculid lice which are common to man, and that one of the anthropoids bears another species of the same genus of pediculoid louse, but which does not occur on man.

The blood-sucking lice, or Anoplura, to which the pediculid lice belong, seem to be derivable from the mallophaga from which they differ structurally and chiefly in a modification of the mandibles into piercing organs which serve to perforate the skin of the host and to make the blood available for food. The same general sensitiveness to host relationship exists as was expressed of the mallophaga. The chemical composition, as shown by the blood serum reactions, which indicate a specificity of blood, seems to be one reason why the four hundred known species are as widely distributed on the mammals and that none have been taken from birds. It aids us to understand why man and the anthropoids may have closely related forms.

Migration from parent to young and from host to host occurs as was stated of the mallophaga, and with some of the same limitations. Here, however, the individuals maintain their relation upon the host more by the form and size of their claws than by grasping mandibular structures such as occur among the mallophaga.

The frantic efforts of a vigorous host would serve to dislodge individuals less well prepared to grasp the hairs. One may well conceive that the struggle for life, the free-for-all, in the louse world was one like that in which the stronger Spartans were produced by destruction of the weaklings, and that after an extended period of such elimination a race was bred that could maintain a foothold with clasping claws that fit a hair with the nicety of a caliper. A careful examination of these clasping organs shows that they can be used upon a hair of almost definite diameter and even of a definite shape. A hair much larger than those of the accustomed host frequently would be too large even to permit the presentation of the claspers, while a hair much smaller could not be held tightly at all.

The next large group of ectoparasites which is known principally in the free state, but which has a large number of members that have undertaken to live upon other animals, as well as upon plants, are known as mites. Instead of feeding on dry plant products and dead animal products, or upon the body fluids they have undertaken to go more deeply into the body. We know them as the itch mites, mange

and scab, and while some of our number may confess an unfamiliarity with either of these it is more than likely that we may have undertaken unwittingly to raise another variety that grows in the skin of the face, and is referred to as the face mite, or demodex.

I shall not undertake to detail the steps by which the free-living forms, in four instances, may be traced more or less definitely to a parasitic condition. We may readily understand that a mite that served as an active scavenger might maintain the habit, and by its continuance upon an animal could readily find a supply of dead skin, hairs and oils, and without the necessity of any unusual power of locomotion could become the itch mite that burrows into the skin. Imbedded as it is, in the epidermis—as of human itch—it is removed from ready access to air, to a degree that respiration is practically impossible.

Within the bodies of our poultry we find an interesting, relatively large mite that lives and thrives in the lungs, tracheae and the air-sacks of the bird. Their life is rather unusual in that they are able to migrate about the tissues of the host, or even out of the mouth without apparent inconvenience. They are taken in with the food of the bird. The parasites feed upon the tissues of the host and give birth to living young, thus reducing to a minimum the hazards to which many of the other forms are subject.

Experiments to determine the power of mites to carry on respiration yield rather negative results, and it is held that many of these which imbed themselves in the body of the host are able to secure sufficient oxygen from the tissues to maintain their bodily activities. In an attempt to determine whether the total exclusion of air would have an effect upon the organism I mixed in vaseline several hundred of the feather-eating analgesid mites that were secured from a dead ostrich, and compared their activities with control specimens that had migrated from the body of the host to form a dense mass about the ocular of a microscope and the neck and shoulder of a bottle that stood upon the laboratory tables upon which the dissection of their host had occurred. At the close of the tenth day about half of the number were still struggling in an effort to creep out of the vaseline and in the course of the next two days the movements ceased completely. The last of the individuals that were not imbedded in vaseline died within fourteen days after their migration from the host. It would appear that the earlier death of the last individuals, by so much as two days, was due more to the exhaustion of the parasites in an effort to escape from the vaseline than to the complete exclusion of air. Therefore, if species of external mites which live normally in the air are so little affected by complete exclusion of air the effect must be less marked upon those which burrow deeply into the tissues and out of reach of free air. The tracheal respiratory organs are reduced or missing, among mites.

The face mites, demodecidae, seem quite thoroughly adapted to live imbedded in the oily secretions in and about the minute hairs of the face of several mammals, and even of man. Here they feed upon the sebaceous secretion, and I have observed instances in which they seem to have chewed the hair bulbs with their mandibulate jaws. To suggest that a person might unintentionally harbor parasites, whatever

the kind, is to invite as vehement a denial as though he were charged with the act of receiving stolen goods. The interest and surprise are even greater when I suggest to you that one-fourth of the faces here have these elongate, six- or eight-legged mites in the pores over the nose, at the side of the nose, and in the furrow between the lower lip and chin, if I may judge from a twenty-eight per cent and a thirty-three-and-one-third per cent infestation in two classes of my students in parasitology.

The face mites are barely able to move about by means of their short, chubby legs. When not in the sebaceous secretion of the hair follicles, therefore, how do they migrate? How do they find a new host? More forceful than the question, "How might they spread from myself to others?" is the one, "How did they spread from others to me?" The substance which one might press out of the skin as a "commedone" or a "blackhead" is not either a worm or a mite, but in that material they may be found in numbers ranging from a single individual to several, if a person is infested. I have found as many as one hundred in a single follicle from a dog infested with follicular mange. It is possible to expel the mites by pressure or by friction applied to these regions of the face, and it is not beyond the realm of the possible that the friction, as of wiping the face with a towel, may serve to dislodge specimens from the pores, or to pick up others that were in the act of migrating from pore to pore over the surface of the face, and thus to my own face, if I chanced to use a towel previously used by an infested person.

A heavily chitinized cuticle, which covers the whole body of the face mite, makes it possible to withstand dessication, or even the effects, for several minutes, of a ten per cent solution of caustic potash, before it is killed. I have observed a mature specimen, while lying on its back in a ten per cent solution of potassium hydrate, to move its four pairs of legs with the rhythm that suggested the co-operative action of the members of a crew of an eight-oared boat.

A brief reference to the parasitic worms will serve to indicate that the hazards of life are such that, in spite of the enormous number of eggs and young, the total number of adult forms does not increase markedly from year to year. It is estimated that *Taenia saginata*, the tapeworm which man may acquire by eating infested rare beef, is capable of producing one hundred and fifty million eggs in a single year; that a liver fluke produces one hundred thousand eggs in its lifetime; and so the numbers might be multiplied at length to indicate that these, and other parasites, must meet handicaps that do not occur in the life of larger animals with which we are more familiar.

The intestinal worms, which by rare chance find their way into the digestive tract of any host, are plunged into digestive ferments that would digest materials like those of the parasite, and in fact this does occur if chance brings them into some animal with a more vigorous digestion, as, for example the introduction of hog lung-worms into the digestive tract of a rat, where a large number are digested. The experimental work of Birge and Birge of the University of Illinois throws some light upon the question of the non-digestion of such forms as

tapeworms, and round-worms, ascarids, which occur in the digestive tract of dogs. The digestive juices were extracted from the pancreas of a dog; they were properly activated and kept in containers maintained at the temperature of a dog's body. Live worms that were taken from dogs were unaffected by the fluid, but if worms were added after first killing one-half, or one-third or the whole of the body by passing a strong electric current through it, only such killed portions were digested, the balance remaining active. What could be the assignable reason? To say it occurred "because they were alive" was not a solution, but when a section of the tubular body of the ascarid, which is scarcely the diameter of the quill of a chicken feather, was slipped over a small porous cup coated with platinum black and filled with hydrogen peroxide, such dead portion was not digested by the digestive fluids. Thus we are led to the conclusion that so long as the tissues are saturated with oxygen or that an oxidizing substance is available the digestive enzymes are broken down and are rendered ineffective. It is believed that the body of the live worms produces materials that oxidize the digestive enzymes as effectively as was done by the platinum black and the hydrogen peroxide, in the experiment that has been quoted.

The progeny of the intestinal worms are discharged by way of the digestive tract of the host, either in the form of eggs that hatch in the soil, or only after being eaten by a new host, or they may be in an advanced stage of development when they pass out of the host. In the moist soil they may live and move with almost the same ease as the free-living forms with which they mingle. Here they may remain alive for long periods, whether they remain moist or wholly dried, some to force their way through the skin into the body of the host and finally into the digestive tract, as the hookworms of dogs and cats, or of man; others to be taken up by hogs, and after a devious course to reach the digestive tract or lungs and there to become adults and in turn to discharge other thousands of eggs.

If time permitted one might outline, in a similar manner, the mode of life and adaptations of the parasitic protozoa, the one-celled animals, to show how they also encounter hazards that relate to food, temperature and dispersal, to each of which the parasite must become adjusted in the period of transition from a free-living state to that in which it depends solely upon a host or a series of hosts for its existence.

The problems of life of the successful parasites, whatever their kinds, are numerous and critical, but each, in its free-for-all struggle, survives if it is resistant, and leaves progeny that resemble it, or it fails in the struggle and thus passes out of existence. It has had its thousandth of a chance, or a ten-thousandth of a chance or less, and failed, while some other competitor, only slightly better fitted for the conditions, will survive and perpetuate its heritage.

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Fakers of Science

E. G. Mahin

The salvation of the world depends upon the development and applications of science. This is a statement that may be considered unassailable. But if anyone objects to this use of the word "salvation" I shall not argue the question or become irritated—I shall simply shift my ground somewhat and reiterate: The hope of the world lies in science and its developments. If it should be that other contentious individuals should manifest a doubt as to the propriety of confining "hope" to such materialistic lines, I shall not even reply, but again side-step and repeat: The whole future of the world, animate and inanimate, is held in the hands of scientists, past, present and yet to be born.

In this evasiveness I can indulge with a perfectly clear conscience because I consider all of these statements as meaning essentially the same thing. In such circumstances one can afford to be generous and to allow another, who may not so regard the matter, to select the term, the phrase, the formula that best agrees with his own ideas upon the subject.

Now if my fancied opponent remains obstinate and unconvinced, I fall back upon a vice that has already become apparent in this introduction to my paper—namely, that of over-indulgence in the pronoun, first person, singular. I speak for myself alone. No one else is involved in any of my statements; no one is asked to accept them unless he likes.

So now the way is cleared, technicalities are brushed aside and opposition is trampled down. Exceptions have been noted by the court and the basis laid for an appeal. But you will not find the present speaker there when the case is called. What I have to say, I say now. In the picturesque language of Young America, take it or leave it. It is all one to me. So now let us plunge at once into seriousness.

Can it be that you have forgotten what it is that I have been saying so many words about? Well, I am simply trying, in all seriousness, to stress the idea that studies in science, the concentration of the human intellect, mass action of human *intellects*, upon the problems of the universe has resulted in enormous benefits to the human race and that there is every indication that future efforts will uncover other vast fields for the application of forces and principles of which our brightest minds do not now even dream.

The fact is that every one who observes intently and who thinks deeply knows that what I have said is true—stripped of all verbosity, redundancy and prolixity of every variety, it is essentially true. Then to the next idea.

When we realize what a serious business is the matter of the health and comfort and happiness of the human race, individually and col-

lectively, and how intimately bound up with these is the matter of discovery and correct application of the scientific principles upon which the universe operates, we may ask the question: What of the man who, in the full knowledge of all this, deliberately distorts the truths of science in order to deceive, to harm or to rob human beings of their benefits, and especially if this be done for personal gain, financial or otherwise? What, in short, of the *faker* of science?

Deception and thievery have always proved to be profitable enterprises, in a temporary sense, at least. How much easier and how much more pleasant a job it is to permit others to do the drudgery involved in high achievement and then magnanimously to shoulder the profits or the credit or whatever gain is involved, and to appropriate it to one's self. How simple a proposition to take the discoveries of science and the scientific achievements of men's minds and to misapply them to one's own financial gain or credit and this, frequently, in a quite spectacular manner, trusting to universal ignorance and inexhaustible human credulity for success in the undertaking.

If one were to attempt to give even scant notice to any considerable proportion of individual fakers of science, and of their fakes, that are recorded in literature the result would be a ponderous volume. Far be it from me to inflict any such attempt upon this grave and dignified body. But I should like briefly to discuss a few outstanding *classes* of fakers, using this discussion for the conveyance of certain personal opinions that have long been struggling for expression.

Schemes for accomplishing work without supplying energy or consuming materials have long engaged the attention of pseudo-scientists. These are so familiar to everyone, under the general head of "perpetual motion" contrivances, that we shall waste no time in discussing them. In most cases work and study have been spent upon such ideas as a result of lack of scientific training on the part of the schemers and we can feel only pity for the misguided zealot who spends the best years of his life in chasing such a phantom. It is only when a device of the "perpetual motion" class is actually produced for demonstration for the purpose of obtaining financial aid or credit for the "inventor" that the latter qualifies for the society of fakers. For he must necessarily know, before that event, that the machine will not work and that the scheme is impractical and he becomes then a plain swindler—a real faker of science.

So much for this ancient class of fakers. I should like to give brief mention, now, to the Free-Energy faker. This is truly a clever and audacious individual. The most recent developments of physical and chemical science have given a tremendous emphasis to the possibilities of utilization of energy stored in the individual atom. This energy is a reality and the problem of its practical utilization is one of the many fascinating fields for future exploration. The general, nonscientific public also has caught something of the vision and, with little or no understanding of the real meaning of the discoveries that have already been made, is nevertheless willing to accord a certain doubtful respect to the scientist himself. Here is the golden opportunity for the faker. Ever on the alert and with an eye to the main chance, he

(metaphorically) nimbly mounts to the shoulders of the man of science, snatches the banner from his hands and bravely rides his steed into public notice. What with his excessive shouting and his skillful use of language, it is small wonder that he absorbs the principal share of attention, for a time at least.

One example shall be mentioned and then we may pass on. In the year 1917 came one silver-tongued Armenian, styling himself Garabed T. K. Giragossian, before certain Congressmen and secured their attention to an "invention" for obtaining "free energy" from the inexhaustible supply furnished by nature. He gave no description of his machine or of the principles employed in its construction or operation. But his references were so splendid and his language so eloquent that he experienced little trouble in obtaining the introduction and ultimate passage of a joint resolution authorizing the government to accept the free use of "Garabed", as the device was called, for the purpose of bringing a speedy end to the war. A clause was inserted in the resolution to the effect that a committee of scientists should first examine the validity of principles and witness a demonstration of a working model of his machine. This proviso may have been inserted as an after-thought,—or it may have been the work of some brutal materialist whose lack of vision kept his feet on the ground. At any rate the demonstration proved a complete failure and "Garabed" turned out to be only one more of the many pulley-and-flywheel devices for perpetual motion.

Dr. C. H. Herty, former editor of The Journal of Industrial and Engineering Chemistry, adds his own poetic comment, thus:

> "The Garabed's completely dead. 'Twas put to sleep through just one peep by a bloomin' committee that had no pity."

What the motives of Mr. Giragossian were, we are unable to state. In the light of his offer to the government we are inclined to be charitable and to suppose that he was, like many others before him, a self-deluded victim of his own lack of scientific training. But when we observe how nearly he came to hoodwinking an important branch of our government we indulge in a shiver of apprehension for what might have been the result had Mr. Giragossian been less altruistic and more skillful in holding fast to his dupes. The human mind is capable of believing anything, however wild, and even in working up considerable enthusiasm in connection with such belief. To support which statement I offer a part of a speech on Garabed, delivered in the House of Representatives:*

> "Mr. Speaker, the miracle of yesterday is the commonplace of today. There was a time when man was perfect in all his parts and elements. He was complete physically. The poet, the painter, the sculptor, the dreamer, in the wildest flights of superb fancy, never caught more than a fleeting vision of that beauty which was given by the Lord to the first man and first woman.

* Congressional Record, Dec. 15, 1917, p. 358.

"Not only was man complete physically at one time, but he was perfect mentally. He knew all philosophy and all science. Mathematical exactness was instinctive with him. He knew and could interpret bird song. He knew where the flower bloom came from, and why. He understood the passions of the tiger. He saw all problems with clear and unmistakable vision.

"He was complete spiritually. He discussed with the Divine the themes of the divinity. He communed with the angels.

"He was so complete in his structure that he possessed the power to destroy his own perfection, and he exercised this power. He sinned. That is to say, he violated some law of harmony. What it was we do not know. Perhaps we shall never know. But we know that it was the exercise of a power by which the integrity of the triple structure was destroyed. I think that touched his every phase and characteristic. It devitalized him physically. The majestic brow receded; the form became bent. Warts and vile protuberances grew upon the skin. The nerves lost control over the muscles, and these, uncontrolled, fell to hideous expression. And it devitalized him mentally. He lost intellectual excellence. He lost the power of discerning truth clearly amidst every confusion and complexity.

"It devitalized him spiritually. He could no longer look clear-eyed upon the angels nor commune in freedom with the God. And in this condition—a physical degenerate, a moral wreck, an intellectual prostitute—he was cast into the wild amid the wild things over which he had held unrestrained dominion."

This, you will observe, is offered in support of the claims for scientific excellence of "Garabed". If you are sufficiently generous you will admit that it completely establishes the case!

The Keely motor swindle is a classic, so familiar to all that it shall here receive mention only. Also the perennial device for "burning" air instead of expensive fuel. Likewise a myriad of other schemes for obtaining something for nothing, that have deluded and bewildered men of all generations.

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It is time now that we should give some attention to the mineral water faker. This gentleman's business is, perhaps, considerably less obnoxious than many others because, in a general way, some of the results are wholesome. Bear in mind, therefore, that it is only to the extent and in the sense that it is a *fake* that we visit our displeasure upon it. Also please remember that our faker of science is the one who shows people not the real science or a correct application of the real science, but a slightly different one, so like the true one (perhaps even a mirror image of it) that the untrained cannot discern the difference. But this slight variation is the one item upon which is based the success, financial or otherwise, of the faker.

Scientifically speaking, the task of the mineral water faker is comparatively simple. It is a fact well known among medical men that many (if not most) people do not drink enough water and that constipation, with all of its attendant ills, is the consequence of such

abstinence. Also it is known that several of the chemical compounds commonly found in ground waters have a pronounced effect (sometimes a wholesome one, if taken in correct quantities) upon the digestive apparatus. Add to this the psychology of illness and health and you have the case. The waters of a given locality are advertised as of a curative nature, the chemist's analysis is published, together with a statement of the physiological effect of each constituent named, and a health resort is established.

Some people suffer from poor health because of overwork (although the number of such is really not as great as we often like to believe), some from *under*-work and great numbers think they are ill when they are not (or are ill because they think they are, which perhaps amounts to about the same thing). These in addition to the people who need more water to drink, as already explained, and to those who chronically disobey most of the rules for caring for their bodies. Induce these folk to believe that a peculiar water from the bowels of the earth, found only in certain famous wells, is the long-sought fountain of health, if not even of youth, persuade them to go to this health resort for a season and a cure is almost certain. They are placed in the hands of skilled dietitians who cause them to eat sensibly and to drink abundantly,—of other attendants who look to it that they shall bathe and exercise regularly and properly,—and the entire atmosphere is made pleasant and cheering. Under the circumstances Nature gets her opportunity and the patient is cured. The cost, in money, has been rather high but it was worth it, wasn't it?

This is all very fine and it is probably true that a cure as the result of deception is better than no cure at all. But I am dogmatic enough to believe that education is better than deception, cure or no cure, and that in the long run it will have a better effect upon the health of our people. The thing that the patient did not understand was that rest, recreation, correct diet, drinking sufficient water (plain monoxide of hydrogen), frequent bathing and rubbing and pleasant thoughts were the cause of the cure, when he innocently considered them mere necessary evils,—and that the mineral content of the water, which he understood to be the curative principle, was only so much bosh and clap-trap, an adjunct to the main business. He could have practiced proper eating, drinking, bathing, etc., at home but did not understand that they were necessary or important. He could have bought at the corner drug store, for twenty-five cents, as much mineral salts as was contained in a thousand gallons of the water he drank, but knew neither this fact nor that the salts themselves had no appreciable effect upon him because of their very small concentration, and that they were therefore unnecessary to the success of the treatment. (Please note that I am not here discussing the so-called "mineral waters" that are found bottled on the market, consisting of ordinary ground waters "fortified" by the addition of quantities of laxative salts.)

And now let me attempt to justify the statement that education is preferable to deception, science to fake, by reminding you that where one sufferer is cured by this benevolent deception, a thousand others

fail of cure because they cannot afford the cost of the deception and because they have not been told how to cure themselves at home, at no cost at all.

* * * * * *

Enter now the Patent Medicine faker. This individual has been with us for a very long time and he bids fair to favor us with his presence for some time to come. Again we notice the essential characteristic of the faker family,—the ability to confuse science with *un*-science, truth with a lie, real medicine with pseudo-medicine. The patent medicine faker relies for his success chiefly upon (a) the almost universal knowledge that scientific medical practice has proved its worth to mankind, (b) the almost universal *ignorance* of what is and what is not scientific medical practice, (c) *quite* universal credulity and (d) the strange fascination that seems to be possessed by mankind for self-dosing. And his reliance is not misplaced. How we love to be ill so that we may become well and how we love to prescribe for ourselves,—or so we think we are doing, while in reality we are responding to psychic suggestion, so cunningly conveyed to us by paid advertisements in newspapers, frequently masquerading as news matter and through which the patent medicine faker prescribes for us.

It has been repeatedly pointed out that the worst feature of the patent medicine evil is the fact that money is so frequently squandered for worthless, or worse than worthless, materials by those who can least afford its loss, and that these same people are so frequently the ones who most need the advice of wise, well-trained physicians. Why self-respecting druggists continue to vend the stuff and why self-respecting newspapers continue to accept money for concealed and unconcealed advertisements, used for the deception of the credulous,—passes my understanding. But I long ago gave up trying to understand a number of things.

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Now, with fear and trembling I arise to pay my respects to the Religious faker. My trepidation is based upon the knowledge that any man of science who essays to discuss any matter connected with religion treads upon dangerous ground. People are extremely sensitive concerning the so-called materialism of our scientists. "Atheism in the colleges and universities" is a phrase with which to conjure. Let me say at the very outset that I am not going to attack religion. Neither shall I defend religion. I shall not discuss religion in any way but I am going to say a few things about religious fakers of science. And again please notice (I am very particular here, of necessity) that we have consistently discussed fakers of science as men who pervert or misapply the truths of science in order to bolster up any case which they desire to make, whether this be through ignorance or "with malice aforethought". I believe I am right in maintaining that it is no compliment to religious ideals to fake anything, anywhere in their support.

The "conflict" between science and religion is at least as old as science. Scientific men, accustomed as they are to rigid self-discipline in methods of thought, basing their conclusions upon demonstrated or demonstrable facts, have long manifested impatience concerning the

irrational superstitions that have attached themselves to religious thought. Not only have certain scientists attacked these ideas very bitterly but many others have felt a rebellion in spirit, mostly suppressed for reasons of expediency. It has indeed been unfortunate for the cause of religion that its exponents have always been slow to accept scientific principles. Giving ground inch by inch, but always fighting, organized religion has kept itself always in the position of the reactionary instead of in that of the enthusiastic supporter of all search for truth by every available method. Many of the foremost religious thinkers of recent times have seen and regretted this anomalous position and there has, of late years, been noticed a tremendous effort on the part of religious writers and speakers to reconcile the conflicting elements and to remove from the church the stigma of always posing as the obstructionist in matters of scientific advancement.

In casting about for means to this end they have made another unfortunate mistake. "Let us be magnanimous," we can imagine them saying, "and admit that organized religion has been reactionary in the past, dogmatic and intolerant to progressive scientific ideas, and clinging to ancient and mediæval superstitions. But let it be so no more." So we have it now that there is no longer opposition to true science. The chasm is closed, the discord is harmonized. The result? Why, science *proves* the truth of religion! People may now be religious in spite of their doubts, because science and the truths of science corroborate the theories of religion. The church has adopted the "scientific method" of reasoning and the problem is solved.

This course of procedure is a mistake, for the simple reason that never, as long as this world shall endure, can science ever corroborate a single *dogma* of religion, any more than it can corroborate a single dogma of any other kind. This is because religious dogma, like any other dogma, is essentially a non-demonstrable theory. It can be neither proved nor disproved and so science can have nothing whatever to do with it. Science is concerned only with hypotheses that are susceptible of test and when it becomes apparent that any theory lies outside that conceivable possibility, that theory immediately becomes impossible of consideration from any scientific standpoint and it must remain a matter for acceptance or rejection, according to the personal inclination or emotions of the individual.

But here is where our faker takes up the matter. If science will not concern herself with our dogma let us have a science of our own! So it has become fashionable for speakers and writers, eminent and otherwise, to adopt the words and phrases of science and to weave them into discussions of religious theory, creating or attempting to create the idea that because the religious exponent himself is scientific, science is therefore of religion. Scientific terms are bandied about with perfect familiarity and handed out with an effrontery that awes the non-scientific hearer and compels his respect, even if it amazes or amuses the scientist himself. This is particularly true in college towns, where great numbers of young men and women are engaged in the study of pure and applied science. Thanks to the reactionary religious

training of the past, these young people have been taught a vast number of things that have to be unlearned when they begin the process of absorbing scientific fundamentals. Now, in order to keep them in the proper channels of religious thought, the possibilities of their scientific training must be counteracted in some manner. They must be impressed with the idea that their "doubts" are only imaginary and temporary and that future training will dispel them because: "I" (the speaker) "have had such doubts and have overcome them, and is it not evident that *I* am scientific?" In addition to this very prevalent vice among the stationary teachers of religion we have numbers of eminent divines going about the country, making a specialty of talks to mass meetings of college students and using the methods above outlined. No doubt they have visited your town as they have ours. These men are usually orators of first distinction. They mix with their addresses a perfectly amazing patter of science. Dinosaurs, relativity, electrons, paleontology, anti-toxins, protoplasm, light-years and gamma rays are the breath of life to them. Even the more or less mature scientist is somewhat hypnotized by the brilliancy of the discourse. It is only on the way home that he begins to realize that the speaker had very little realization of the true meaning and significance of the half of what he said and that he had been guilty of brazenly faking science in order to appear to prove something that, in the very nature of things, can not be proved.

Unfortunately the young student is dazzled by this procedure because he is in a period of his development where he is only beginning to think logically and independently about the deeper things of life and he is very likely to regard his religious instructor as one of his scientific authorities and to be led to put aside real questions that should be decided, if his future training is to be along sane and logical lines. If the student is really serious-minded his doubts cannot be permanently satisfied in this way and he will not be content with the plan of thinking along one set of ideas within the laboratory and another, incompatible with the first, in the pew.

It may appear from this that I regard it as unfortunate that a young man should be won to religion by pulpit orators. Not at all. As it was remarked in the discussion of the Mineral Water faker that a cure as the result of deception is probably preferable to no cure at all, so it may be better that a man should be won to a life of rectitude by a religious faker than that he should ultimately fail to see the real significance of life. Yet here again I adhere to the idea that deception is unnecessary and that in the long run more people will be attracted to religion by the policy of playing fair and telling the truth, for if they think at all they will find out the truth sooner or later.

Why must our religious leaders ever persist in standing upon ground that they will be compelled to abandon later, just as they have stood upon and fought for ground that later had to be abandoned, through all the history of religion? Why must they insist upon giving so much prominence as essentials to the views and theories of men who lived in the very infancy of our civilization, instead of standing upon the simple *and absolutely unassailable* proposition that *religion is*

life and service? Why, in short, must we have faking of science, where science, with or without faking, has no connection with the subject?

* * * * * *

It may appear that in this discussion I have dealt harshly with well-intentioned classes of people,—that I have magnified a fancied trespass upon our domain into a well-nigh capital offense. But, fellow scientists, in my profession, as in that of many of you, I associate constantly with young people, eager to learn of the whys and wherefores of life. In the college is eternal spring-time of youth. We as teachers, may eventually grow old but, figuratively at least, our classes never do. I cannot look into the faces of inquiring youth day after day, year after year, and forgive myself for any deception regarding the subject I am teaching. How, then, can I forgive deception on the part of other teachers? If we lie to our students we are unworthy of the high duty that is ours.

For all of us who are teachers of science, let us note that science has one insistent demand, which is that we shall teach the truth, according to our best lights, welcome or unwelcome though the truth may be to others.

So for our fakers of science. Their name is legion, though we have discussed but a select few. Wherever there is a truth there is a corresponding untruth that may be made to resemble the truth and if there be any possibility of temporary profit, credit or honor in exploiting the untruth, the faker arises, ready for the job. The work of progress is thus complicated by the efforts of those who persist in pulling in the wrong direction. In this connection I am fond of quoting from Thomas Carlyle, who wrote:

> "We have, simply, to carry the whole world and its businesses upon our backs, we poor united Human Species; to carry it, and shove it forward, from day to day, somehow or other, among us, or else be ground to powder under it, one and all. No light task, let me tell you, even if each did his part, honestly, which each doesn't, by any means. No, only the noble lift willingly with their whole strength, at the general burden; and in such a crowd, after all your drillings, regulatings, and attempts at equitable distribution, and compulsion, what deceptions are still practicable, what errors are inevitable! Many cunning, ignoble fellows shirk the labor altogether; and instead of faithfully lifting at the immeasurable universal handbarrow with its thousand-million handles, contrive to get on some ledge of it, and be lifted!"

Carlyle was discussing neither science nor fakers of science, yet his remarks could scarcely be more apropos of any other subject. Beside this eloquent enunciation of the problem of life and this denunciation of the obstructionist of progress, our remarks are feeble and impotent. Yet, until another Carlyle shall arise to lambast the modern faker of science, we shall have to be content with saying in our own way, the indignation that is in us. This I have tried to do.

Purdue University.

Prehistoric Indiana Archaeology.

S. F. Balcom.

First impressions are responsible many times for our persistent ideas of things. The colored maps of the school atlas, which divided the continent into sections based on political lines, stamped on our minds certain squares and irregular forms as constituting the divisions of what we are pleased to call the new world. Physical Geography corrected our ideas to quite an extent and we remember that there is an eastern and a western mountain chain in our portion of the continent, and that the latter extends through Mexico and Central America and on into South America. But how many are there who, having had opportunities of traveling over the country, take note of its formation and realize how one part after another has developed and is dependent on some other part, as for instance upon the Gulf of Mexico?

In a paper read before the Indiana Academy of Science a few years ago, Mr. M. S. Markle called attention to the fact that the glacial drift reached as far south as the Ohio River, as evidenced by local flora in certain portions of Indiana and Ohio. And that plants common to an Arctic flora still remain in bogs and cool, shady ravines, and at times are surrounded by the southern flora that came in the wake of the retreating ice. A study of the primitive races in our northern continent shows traces of a shifting about, quite similar to these marches and countermarches of nature in building the land. And from remains which the Indians have left we are led to believe that the Indian stoic of the woods in Ohio knew as much of the geographical layout of the country,—that is, its mountain territory, its lake country, its prairie region, its converging valleys and their relationship to the great gulf at the south as do most of his civilized successors, excepting, of course, those who have made a special study of the face of nature in a geological and geographical way. For on the Scioto River in Ohio are remains of a race which speak of an intertribal trade extending to the Atlantic on the east, along the Mississippi to the gulf on the south, and then west to the mountains of Mexico, if not to the canyon country by way of the Red River or other water courses.

Geology explains to us the formation of our continent, and how it has been formed on similar lines to that of the old world, yet it may be said to have an individuality of its own. Anthropology says the same of the primitive American races, for a development peculiar to themselves is indicated, in which certain characteristics of physical make-up and certain elements of the various languages, point to a common origin, and as not having been materially influenced by any old-world culture. It remains for Archaeology to trace the routes by which the branches of that prehistoric Indian race developed,—diverging in some instances, combining in others, and yet through it all leaving traces more or less distinct which point out the paths which they trod.

The director of the Field Museum at Chicago advised me, upon inquiry, that some five distinct cultures are traceable in Illinois; and Prof. Mills, Curator of the Ohio State Archaeological and Historical Society, says that about as many minor cults are said to have existed in Ohio, although they have not been definitely traced. Indiana, in between, must have harbored all of them more or less, and an interesting field, consequently, is here open for investigation.

The great pyramidal mounds at Etowah in Georgia and Cahokia in Illinois, with their associated tumuli, are evidences that a race with great power and high ideals once occupied the Mississippi valley. They seem to have passed up to the headwaters of the Mississippi and also branched off into the comparatively mild valley of the Ohio, leaving traces in Indiana and Kentucky.

In Ohio two quite distinct groups developed, reached their zenith and passed into oblivion, for their characteristics were not common to the native tribes which occupied that section at the beginning of our historical period.

The earlier of these two cultures is marked as peculiar by having been the first to build immense earth walls. The largest of these embankments are located at a point some 40 miles north of Cincinnati, on a headland with steep sides and some 200 feet above the Little Miami River which adjoins it, and is known as Fort Ancient. They inclose about 100 acres of level ground and are over 3½ miles in length; they contain about three million cubic feet of earth which was carried from a distance to construct them. In places they are twenty feet in height with a base about four times the height. Openings were left in the embankment every 200 feet or so and these openings average something like 20 feet. This feature interferes with the inference that they were the walls of a fort, and point rather to their being of a ceremonial nature.

At Marietta, Ohio, at the mouth of the Muskingum River, and at Newark, in the upper Muskingum valley, some 40 miles east of Columbus, were traces of this early Fort Ancient culture in the form of pyramidal mounds at the former place and remarkable earthworks at the latter. These embankments while not being any ways near as large as those at Fort Ancient, being only from about 2 feet to 8 feet in height, were constructed with a wonderful geometrical accuracy. They were in groups enclosing areas of from 2 to 50 acres, and the groups were distributed over an area of four square miles. Many of these groups being connected by passageways outlined by low parallel walls 8 to 12 feet apart, indicating an extensive ceremonial use on a tremendous scale.

Large sepulchral mounds with indications of cremation burial are lacking with the culture or cultures at Fort Ancient and at Newark, but in the Scioto valley a culture developed to an almost unbelievable perfection. Here earth embankments of wonderful geometrical accuracy are accompanied by sepulchral mounds which contain evidences of ceremonial rites in connection with elaborate cremation burial, the most remarkable of artistic pottery and carving in stone which undoubtedly will place them at the forefront of stone-age peoples, and above any

others in the delicacy of their pottery and the artistic proportion and finish of the same; and above all the accurate delineation of animal and bird forms carved in pipestone, which show the striking qualities of a master sculptor by presenting the pose and even the facial expression of animals and birds, which were at the same time fashioned in the form of platform pipes. Along with this are evidences of a nation-wide inter-tribal trade, for the mounds contain copper which must have come from the great lakes or Mexico; large quantities of mica probably from North Carolina; hematite apparently from Missouri; galena ore similar to that of Illinois; ocean shells from the Atlantic or the Gulf; and, most remarkable of all, obsidian in very large specimens of spear heads which could not have been quarried closer than Mexico. In all of this they formed a distinct culture far above the Newark stage mentioned.

At Anderson, a county seat northeast of Indianapolis, is a small group of earthworks similar to those at Newark, and are distributed over an area of about five acres. They are known as Mounds Park and are located on a bluff adjoining a beautiful stretch of White River. The park is reached by both traction and street car lines from Anderson; it has a large shelter house and would be an ideal place to invoke the inspiration of the leaders of that unknown race, for the archaelogical researches now contemplated among these examples of their handiwork. One of the circular embankments of this group covers about two acres, in the center of which is a small ceremonial mound; it has a single gateway with level ground leading to this mound. The earth for this embankment was taken from the inside, forming a ditch about 8 feet in depth, which with the height of the embankment added presents from the inside a slope of quite imposing height. This same feature of an interior ditch exists at the embankment in the Fair Grounds at Newark, Ohio.

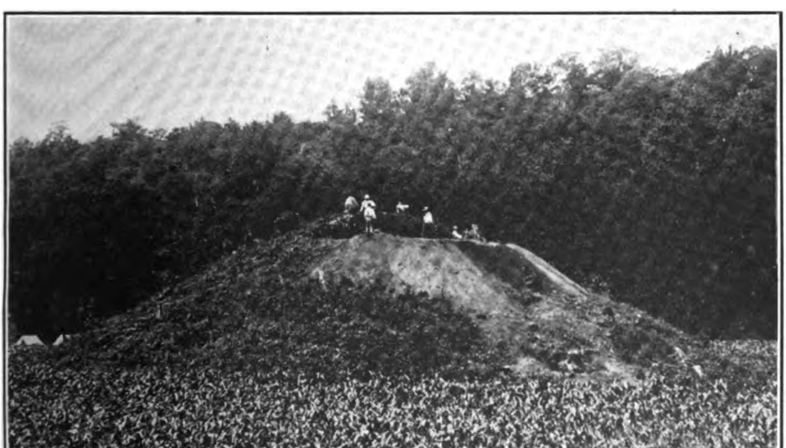

Fig. 1. Exploration of Adena Mound.

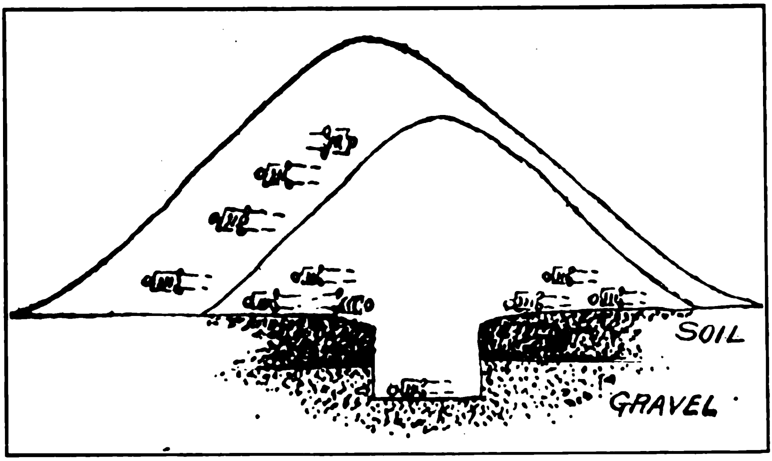

Fig. 2. Cross-section of Adena Mound.

Figure 1 shows the first stage of work in excavating the Adena mound near Chillicothe, Ohio, done some 20 years ago by Prof. W. C. Mills, Curator and Librarian of the Ohio State Archaeological and Historical Society. Figure 2 shows by a cross-section of the mound how it was built at two separate periods. It will be noted that the grave in the middle of the original mound is the only one placed below the ground level, the others being at four different levels, marking

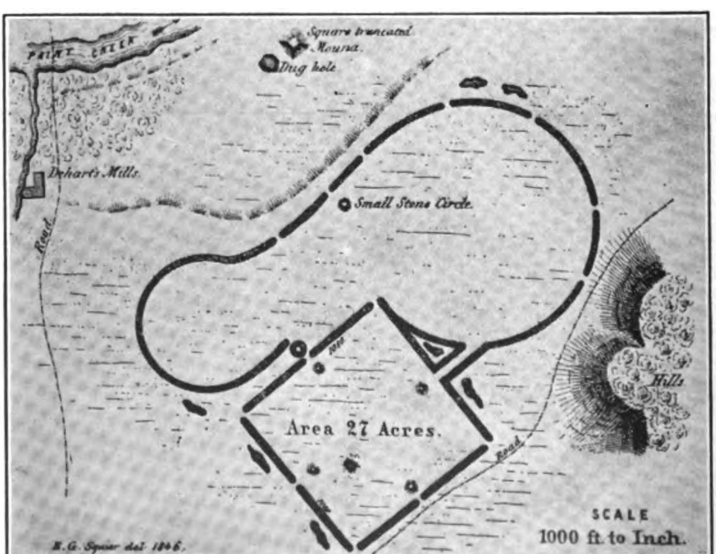

Fig. 3. Square truncated mound and the Baum geometrical earthworks.

apparently that many different periods or stages in the construction of the mound. This central grave was on a large scale, being about 12 by 14 feet and nearly 7 feet in depth, walled with logs, which had decayed, leaving only the space or mold. No copper ornaments were found in this grave, but fine specimens were found in some of the other graves, indicating that the remarkable use of copper came a little later than the date of this the most pretentious of the burials.

At the Baum earthworks and sepulchral mounds, some 14 miles from Chillicothe, shown in Figure 3, a radical change in custom and ceremonial rites was found in the square truncated mound, explored by Squier and Davis in 1846, from those at the Adena Mound. At the latter place logs were used in the formation of sepulchers but here they were used upright, forming an enclosure which was a perfect circle 26 feet in diameter, with the posts set 10 inches apart. It was paved on the ground surface by logs radiating from the center. All interments were within this enclosure and were found at various levels placed upon layers of sand, indicating a progress in the construction of the mound similar to that of the Adena mound. Here to somewhat larger extent than at the Adena mound the practice of cremation was found, but at each place it was incidental and not the general practice. No copper or foreign substances were found, and the few stone articles did not show high aboriginal art and it is inferred that the construction of the mound antedated that of the earthworks. The construction of a square monument around a circular mortuary chamber would indicate a relationship with the early cult which built rectangular truncated mounds in the Ohio and Mississippi valleys. And the incentive prompting the use of an unusual geometrical feature in the construction of this mound would seem to be the governing incentive leading to the construction of the ideal group of earthworks found at this place.

A group of earthworks identical in nature with the Baum group except that the arrangement places the smaller circle adjoining the square enclosure and both connected with the larger circle, is located about 8 miles south of Chillicothe, and known as the Harness mounds, named for the original owner of the land. A very large sepulchral mound is associated with the earthworks, but in this case it is inside of the large circular embankment and at a point such that it forms the prominent feature of all three enclosures. This group was surveyed and examined by Squier and Davis in 1846, and was completely explored by Prof. Mills in 1903. It was elliptical, being 160 feet long, 85 feet maximum width and about 20 feet maximum height. The height of the walls of the large circle was about 4 feet, with the walls of the smaller circle somewhat heavier and those of the square heaviest of all. The walls are unaccompanied by a ditch and the square incloses some 30 acres, the larger circle containing about one-half more than the square. While at the Adena and Baum mounds the practice of cremation was exceptional, the reverse obtained at the Harness mound, for here separate burnt clay or puddled platforms, or basin-like cists, were prepared for the cremated, or more often partially cremated, remains. These receptacles were in most cases for individuals, but in some cases four burials were placed on a platform and occasionally

cremated remains and perfect skeletons were found occupying the same platform. As at the Baum mound, the burials were within a mortuary chamber, outlines of which could be traced by the post molds left after the decay of the wood. A wealth of ornaments, utensils, artifacts and weapons were placed with the remains, as may be judged by the fact that Prof. Mills secured 12,000 specimens from the Harness mound after two previous explorations for other institutions had been made. Among these articles were those of copper, flint, obsidian, mica, slate, bone,

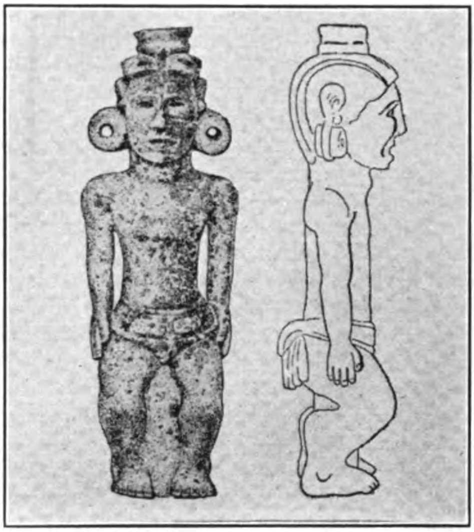

Fig. 4. Effigy pipe from Adena mound.

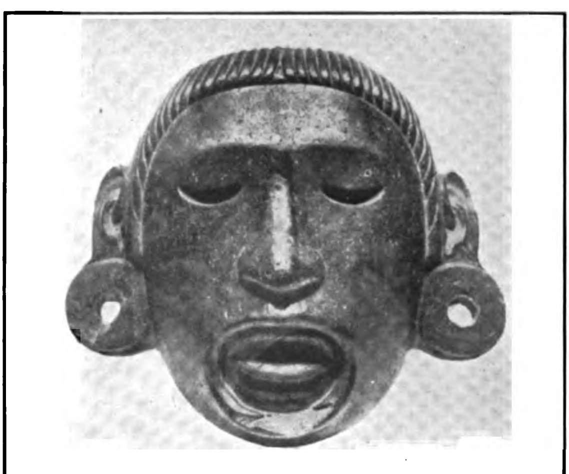

Fig. 5. Mask of Mexican god Xipe.

ocean shells, pearls, crystals of galenite and large lumps of lead ore, also a few platform pipes of limestone and steatite. Most abundant of the copper pieces were the spool-shaped ear ornaments of various sizes and make, and are most important by indicating an inter-tribal trade extending to Mexico. They were found on each side of the head in the cases of uncremated burials, so were judged to be ear ornaments. That they were used as such is substantiated by an effigy tubular pipe found

Fig. 6. Copper Ear Ornaments.

in the Adena mound (see Figure 4). This figurine is a peculiarly Mexican design, and similar ear ornaments appear in carvings of most Mexican gods or idols. This is plainly to be seen in Figure 5, the mask of a Mexican god in the British Museum. This god Xipe was the Mexican deity known as the God of Sowing, and the invocation to this god is interesting to us here in the land of maize or Indian corn, as it voices the following appeal: "Put on your golden garment; why does it not rain? It might be that I perish,—I, the young maize plant." And yet no similar carving representing a deity or idol has been found among the American Indians. It is said that idolatry was unknown in Mexico previous to the reign of the Aztecs. Possibly this Ohio culture antedates the Aztec period. One of these copper ear ornaments is shown in Figure 6. It is in five separate pieces, hammered from the thin sheets of copper found frequently in the graves. It was a far cry from Ohio to old Mexico, but aboriginal man seems to have been equal to it in more cases than one.

Another characteristic relic of this latter culture is the grooved axe, made of the hardest stones, mostly of granite. They had some special use, for they are peculiar to the Ohio valley and the territory west, of which Illinois is about the center. They range from considerably less than a pound in weight to over thirty pounds, and a majority

of them are marvels of symmetrical carving and polishing, and how they had the skill and patience to work them out in granite by hammering and rubbing with other stones is almost beyond comprehension. They are rare in the eastern and southern states and none to speak

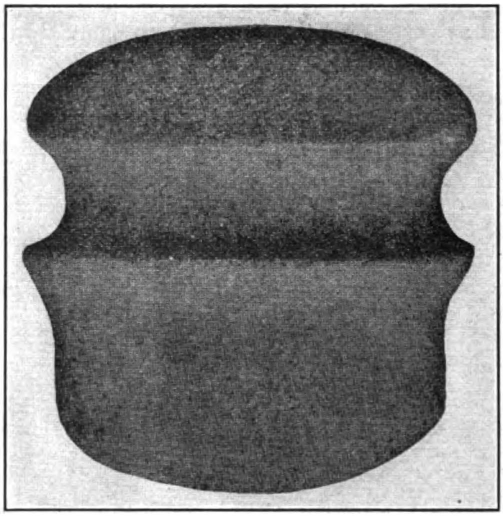

Fig. 7. Grooved Stone Axe.

of are found in Mexico. Figure 7 shows a most symmetrical grooved axe. While its symmetry is most striking, it would not be expected that art features would be worked out in granite. The polls of these axes are usually as carefully proportioned as the blade and seldom show hard wear, although a good many show rough usage. The contrary is usually the case with the blade, as a large proportion show evidences of having been carefully worked over, as in case of the specimen illustrated, which evidently has been worked over and over to give a sharp cutting edge. The deep groove is a problem, for the work to secure it is all out of proportion to what would be necessary to hold a withe wrapped for a handle. The use, whatever it might have been, to which this implement was put, must have been a most important one, and one requiring skill and accuracy. It has been thought that the spalls, flakes or blanks chipped from masses of flint for use in subsequently fashioning arrow and spear heads were secured by knocking them off with hammer stones. This would seem a very crude process for so delicate a requirement. While the writer has not known of the grooved axe or its companion piece, the symmetrical and sharp-edged celt having been mentioned as suitable for this flaking process, that method is offered here as a possible solution. Flint specimens are found which are worked to a knife edge and to a needle point, and it is understood to have been done with a notched bone implement under steady and skilful pressure. It is known that flint and glass work with a cleavage

produced by a shock or pressure acting strongly in any desired plane, as in cutting glass with a diamond. It occurs to the writer that a heavy, symmetrical tool with a reasonably good edge, held firmly in exactly the right position and tapped carefully in the proper or necessary way, would come the nearest to producing desired results of any method that the aborigines could have employed. The grooved axe of granite or diorite, to give a tough, homogeneous texture; perfect symmetry in shape, to give a pressure or shock that could be calculated and depended on; a deep groove to provide for a close grip of the handle, that an exact position of the implement might be secured and a firm contact be had with the material to be worked upon; would apparently give an implement exactly suitable to their needs. And great credit should be given them for so perfect a tool and for the remarkably perfect artifacts that were produced in flint, jasper, chalcedony and obsidian.

We, then, here in Indiana, are in the environment of a most wonderful archaeological field which is beginning to claim attention because of its remarkable attainments in the stone age, and further than that we are in the center of a territory which was occupied apparently by a culture antedating the first of the two cultures mentioned in Ohio, that is to say the people who erected embankments and mounds along the Mississippi valley, traces of whom have been found in the lower Wabash valley.

Prof. Moorehead made extensive explorations at the Cahokia mounds, across the river from St. Louis, this past season, and the results will be of great interest. Prof. Moorehead made explorations which gave the exhibit of Ohio archaeology for the World's Fair in Chicago, which is now in the Field Museum at Chicago, and has since then been Curator for the Phillips Academy at Andover, Massachusetts. The Cahokia explorations as reported by him will surely throw much further light on the progress of this ancient aboriginal race from the South to their final abiding place in Ohio.

Why, then, should we not take steps to unravel some of the mysteries connected with a race which stood head and shoulders above the stone-age peoples of the Old World, and who as a people in historical times have shown themselves to have been in the front rank of uncivilized aborigines, having a personality, independence and ability far above other savage races?

We have occupied their lands, turning them into vast wealth. We have used their names of places and things which have given us the most picturesque feature of our language. So it should be with gratitude as well as pride that we take up Prehistoric American Archaeology and make it the beginning of American History.

Indianapolis.

Preparation and Use of Collodion Sacs in Exalting Micro-Organisms.

Charles A. Behrens.

The conception of enhancing the virulence of micro-organisms by growing them *in vivo* in a hermetically sealed permeable membrane introduced collodion sacs. By this method the organisms are enabled to develop unaffected by the action of the phagocytes and at the same time permitting their soluble injurious metabolic products to diffuse more or less out while the highly nutritive body fluids of the living animal pass in.

This idea was first attempted in 1893 by Morpurgo and Tirelli[1] in their cultivation experiments with the tubercle bacillus. The bacteria were placed in celloidin capsules which were introduced either subcutaneously or in the peritoneal cavity of rabbits.

Metchnikoff, Roux and Salimbeni[2] in 1896 really introduced the collodion sac method when they demonstrated that the toxin of the cholera germ would very readily diffuse through the walls of these sacs when placed in the peritoneal cavity of guinea-pigs. Since then this method has received a great deal of attention and notable results have been obtained in increasing the virulence of various micro-organisms.

The year of 1898 is rather memorable for its accomplishments along these lines. The germ of pleuro-pneumonia was successfully cultivated at this time by Nocard and Roux[3] by utilizing the collodion sac method. During this year by using this method Nocard[4] increased the pathogenesis of the tubercle bacillus, which was human in origin, so that it proved fatal to chickens.

At this time Vincent,[5] employing the method, pursued his research upon converting saprophytic bacilli (B. megaterium and B. mesentericus vulgatus) into pathogenic types.

Podbelsky[6] by applying the same principle showed the destruction of the spores of the Hay bacillus *in vivo*. Due to the difficulty of preparing collodion sacs he made tubes out of reeds. A reed sac, which is even more permeable than one prepared of collodion, is made from the tubular membrane lining the central canal of the bulrush.

It is prepared briefly as follows: Common bulrush reeds, if fresh, are boiled for about 15 minutes. If dry, they should be autoclaved for 60 minutes at 115° C. The end of the softened reed is sharpened as

[1] Archives Ital. de Biologie, Vol. XVIII, p. 187—1893. Ref. in Centrabl. f. Bacteriol., Bd. XIII, p. 74—1898.

[2] Annales de L' Institut Pasteur, Vol. X, p. 261—1896.

[3] Annales de L' Institut Pasteur, Vol. XII, p. 240—1898.

[4] Annales de L' Institut Pasteur, Vol. XII, p. 564—1898.

[5] Annales de L' Institut Pasteur, Vol. XII, p. 787—1898.

[6] Annales de L' Institut Pasteur, Vol. XII, p. 431—1898.

one would sharpen a pencil, so as to expose the membrane lining the central canal. A desirable length of this membrane is denuded. One end is tied firmly and by means of a glass rod it is turned inside out. A glass tube is fitted into the open end of the sac and fastened with strong thread. The sac is filled with distilled water and sterilized. The fluid is removed from the sterile sac and replaced with a suspension of the organism. The sac is tied shut and the glass tube removed. The end is covered with melted gum lac. The thus prepared sac is placed in the peritoneal cavity of the animal.

The method of preparing collodion sacs as first carried out by the Pasteur Institute is quite different from the present-day procedure. The collodion of desirable consistency, which is in a cylinder, is inclined at a suitable angle. A glass tube of small diameter with a closed rounded end is inserted into the solution and rotated until a surface of collodion of sufficient thickness has been deposited upon the tube. This tube is then rotated in the air until the collodion has set and is no longer sticky.

With a scalpel the upper edge of the collodion layer is cut circularly. The thumb nail is used to turn back upon itself this even edge of the collodion sac. By turning the sac inside out it can be slowly peeled off like a "glove finger." The sac is then everted and distended. A small piece of glass tubing is fitted into the open end of the sac and fastened with thread which is then coated with collodion. The sac is filled with water, suspended in water in a flask and sterilized.

The water is removed from the sac with a sterile pipette and the suspension containing the germs under investigation introduced. The sac is closed with a sterile rubber stopper. This plug is dried and painted with collodion. Instead of closing the opening of the tube in this manner, the glass tube which is fitted into the sac can be drawn out into a capillary beforehand. After the sac has been sterilized and inoculated with the organism the end of the capillary tube is sealed in the flame, thus closing the sac.

In view of the fact that the sac is liable to break, especially if kept in the animal for months, Novy[7] introduced a perforated glass tube which has been drawn out into a capillary, into the sac. The sac is attached to this tube. The apparatus is sterilized, inoculated and sealed in the usual way.

McCrae,[8] and a little later Harris,[9] who slightly modified the former's method, prepared sacs by introducing the hot end of a small glass tube into a gelatin capsule. When cold the tube becomes fixed and is painted with moderately thick collodion which is allowed to dry. It is then rotated in the air so as to permit the solution to dry. This procedure is repeated several times until the desired thickness of collodion is obtained.

The gelatin inside of the collodion covering is removed by introducing hot water into the tube, and also by placing the capsule in hot

[7] Laboratory Work in Bacteriology, pp. 498, 499—1899.
[8] Journ. Exp. Med., Vol. VI, p. 635—1901.
[9] Eyre, Bacteriological Technique, p. 358—1913.

water. The liquid gelatin is pipetted off. The apparatus is sterilized and prepared for introduction into the animal's body in the aforedescribed manner.

Grubbs and Francis[10] utilized the perforated tube heretofore referred to, the openings of which are obliterated with gelatin. The outside of this tube is coated with several layers of collodion and the gelatin removed by means of hot water.

The method of preparing collodion sacs as carried out by the Pasteur Institute is difficult. The difficulty is in separating the collodion casing from the glass tube. Gorsline[11] has overcome this and by his method the sac can be prepared with ease. He selects a tube, which may be a test tube, with a 2 mm. opening in its rounded end. The opening is closed with a thin film of collodion. The tube is then rotated in the collodion in the usual way. The sac is removed from the glass tube by filling the tube with water. By constant blowing the water is forced through the opening, allowing it to run between the outside wall of the tube and the inside of the sac, and thus separating the latter from the former. The top of the sac is cut loose from the tube and the sac is slipped off. It is then immersed in water. Its subsequent preparation is similar to that previously described.

The method of preparing the collodion sac for this work is that of Gorsline slightly modified. The technique of sealing the sac containing the suspension of micro-organisms, however, is entirely different from that described by other experimenters.

The procedure of preparing these sacs is as follows: Freshly prepared collodion is used, the consistency of which depends upon whether or not very thin or thick walled sacs are desired. This may be regulated by diluting with a mixture of equal parts of alcohol and ether or by exposing in the air and allowing it to evaporate. This solution must be free from bubbles. A clean tube about 300 mm. by 8, 10, 14, 16 18 mms. with one end rounded with a small opening (2-4 mm.) in the center is used. The outside of the tube is wiped perfectly dry after being moistened with a five per cent glycerin solution. This leaves a very thin film of glycerin on the wall of the tube and facilitates removing the collodion covering from it.

The opening in the end of the tube is closed by painting it over with a film of collodion and allowing it to dry for about one minute. The tube is rotated several times in the collodion, which is in a glass cylinder inclined at a desired angle. The tube is then withdrawn, care being taken that it does not come in contact with the glass container. It is rotated in a horizontal position until the collodion hardens. If a thick walled sac is to be made this process may be repeated several times. The collodion-covered tube is then held under the tap and water is run onto it. By filling the tube with water and by blowing, the sac is removed as in the Gorsline method. At this stage if the collodion

[10] Bulletin No. 7 of the Hygiene Laboratory of the U. S. Marine Hospital Service —1902.

[11] Contributions to Medical Research, dedicated to Victor Clarence Vaughan by colleagues and former students of the Department of Medicine and Surgery of the University of Michigan, pp. 391-393—1903.

cover has not perfectly solidified, bulging will occur. The sac is then immersed in water, where it is practically invisible.

A properly made sac will not rupture if one were to blow into it with all one's might. They are tested in this way before being used.

By this method sacs for dialysing purposes, as described by the author[12] in a previous article, may be prepared with ease.

The top of the sac is cut even, filled and immersed in distilled water in a cotton stoppered flask or tube. It is sterilized preferably in streaming steam or in the autoclave at 105 or 110° C. for 10 or 15 minutes.

The sac is now ready to be inoculated with a suspension of organisms. A sterile pair of forceps is used to remove the sterile sac from the container in which it was sterilized. This sac is transferred to a sterile short tube or held in an upright position with sterile filter paper. The water is removed from it by means of a sterile Pasteur bulb pipette.[13] With a similar pipette the suspension of organisms is introduced into the sac. The walls of the open end of the sac are dried with sterile filter paper and pressed together with a flat-surfaced sterile pair of forceps. Using a red-hot flattened iron wire or spatula, this surface is seared and then coated with several layers of collodion.

The supposedly hermetically sealed sac is tested by taking hold of it with sterile filter paper and applying gentle pressure. If it is found found to be satisfactory it is placed upon sterile filter paper in a sterile dish and covered.

The finished sac is now ready for insertion into the peritoneal cavity of a desired animal. For this purpose several animals are available. Guinea pigs, rabbits, rats, dogs, sheep and chickens are most frequently used. In this work the first three animals were employed.

In the case of the guinea pig and the rabbit, they may be held firmly upon their backs on an animal-board. If a suitable animal-board is not available they may be tied down in this position, as in the case with rats, by fastening cords to each leg and tying over a bridged board.

The hair is removed from the abdomen with a pair of scissors, and after lathering well with soap and water the area is shaved. Alcohol and mercuric bichloride solution are used to disinfect this surface.

After etherizing the animal a small incision along the median line is made through the skin of the upper part of the abdomen. The abdominal cavity is opened up next. With sterile pressure forceps the abdominal muscles are held up and the peritoneal cavity is exposed.

The collodion sac is picked up with sterile forceps and introduced into the cavity and pushed well back under the aponeurosis. With a curved needle and silk thread the cavity is closed and the surface disinfected. The skin is likewise sewed; also disinfected; dried with alcohol followed with sterile filter paper and finally covered with collodion.

The sac remains in the animal from forty-eight hours to several weeks and in some cases months. After the sac has remained *in vivo*

[12] Proceedings of the Indiana Academy of Science, pp. 265, 266—1916.

[13] Proceedings of the Indiana Academy of Science, pp. 266, 267—1916.

the required length of time the animal is etherized. The peritoneal cavity is opened aseptically and the sac removed.

If the sac has been in the animal body for weeks it is surrounded with a fibrous sheath. In this case the sheath is removed before the sac is opened.

The bottom of the sac is sterilized by means of a red hot searing iron, wire or glass rod. With a bulb pipette the content, which is milky in color, is removed, examined and resaced or cultivated *in vitro* or used for classroom work.

By this method the virulence of micro-organisms may be enhanced markedly and it is advantageously used to bring out capsule formation, especially when the germs are so attenuated that their pathogenesis cannot be exalted, as may be the case of Micrococcus Tetragenus, Micrococcus Pneumonia and others.

These cocci and B. Pneumonia (Friedländer's) under this condition form enormous capsules which can be used for classroom work.

Purdue University.

Saprolegnia.

F. M. Andrews.

In the Saprolegnieae the sporangium is a somewhat club-shaped cylinder which sooner or later is cut off from the rest of the filamentous structure of the plant by a transverse wall. This sporangium is of varying length, but ordinarily its length exceeds its greatest diameter from four to ten times. Aside from the presence of a transverse wall, one thing that attracts the attention of the observer is the much more grumous or densely granular nature of the protoplasm. This latter condition is generally quite conspicuous in parts or organs that are or are becoming reproductive centers of various kinds.

This dense protoplasm of the future zoösporangium finally divides into more or less polygonal areas. Sometimes these areas show a somewhat rounded appearance and the transverse wall which confines them to the end of the filament is slightly rounded or arched toward the apex. The zoösporangium opens at the end and preparatory changes in the contents lead to the final expulsion of the zoöspores. There are questions, however, concerning this process which are still unanswered and which deserve attention.

The transverse wall above referred to is not always straight at first but may become curved at a later period, in some members of the group Saprolegnieae, as in some cases in Saprolegnia and Achlya. In the latter, especially, it is often straight at first or slightly curved from the tip, whereas later it is curved apically, particularly when the zoospores are escaping. At this time, and even before at times, the thin transverse wall is sometimes curved apically due to greater hydrostatic pressure back of the zoösporangium, notwithstanding the considerable swelling of the contents of the zoösporangium. This curving outward of the transverse wall frequently occurs at first whether a new zoosporangium is to be produced or not in the hull of the old zoösporangium.

"The distinguishing mark of Saprolegnia," says de Bary,[1] "is that the spores are in the motile state as they issue from the sporangium, and that the branch of the thallus which bears the sporangium grows through it when it has discharged its spores." In Achlya a branch is formed laterally and beneath the transverse wall. This new branch becomes the zoösporangium after development.

An illustration of the apically directed or curved transverse wall is also to be seen in Saprolegnia Thuretis at times, as illustrated by Nathansohn,[2] which is due to greater hydrostatic pressure probably from the first in the main filament than in the zoösporangium, notwithstanding the swelling process in the latter. This wall is not form-

[1] de Bary, A., Comparative Morphology and Biology of the Fungi, Mycetozoa and Bacteria, 1887, p. 143.

[2] Nathansohn, A., Allegemine Botanik, 1912, p. 303.

ing a new zoösporangium in the old one, although the old zoösporangium is probably due to external conditions, as stated by Pfeffer,* in various plants, and these may even prevent at times the formation of sporangia. A deficiency of food, says Pfeffer,† may cause the formation of zoospores or oöspores in Saprolegnia, whereas with some substances no reproductive organs are formed and again with other food substances the formation of oögonia are favored.[1] The various conditions also account for the difference in the latent period of the spores of this plant, which, as stated by Pfeffer[2] and observed by different investigators, ranges from 8 to 10 days as observed by Klebs[3] and 45 to 145 days according to de Bary.[4] Also the zoöspores are especially influenced by various conditions, among these being the attraction by certain substances of which the phosphates are very active.[5]

Inasmuch as the representatives of this division of the fungi are, like some other plants, rather susceptible to some or all of the above mentioned conditions, they tend toward some variation from the forms ordinarily observed. In many cases fish of various kinds are attacked by this fungus and extensive epidemics, as stated by de Bary,[6] of fish in the English and Scottish rivers and elsewhere have occurred. The writer has observed, however, and can confirm de Bary's[7] statement, namely, "that healthy gold fish may continue lively and free from the Fungus for months in water in which Saprolegnieae kept purposely in large quantities were forming an abundance of spores."

The writer has observed insects of various kinds on which, on one occasion, a heavy growth of Saprolegnia was present. The zoösporangia of all of these were formed in the usual manner at first, but when new sporangia were being produced in the first ones some departures from the usual order were noticed. This will be made clear by an observation of Figure 1. Usually, as is well known, but one new zoösporangium is formed by growing up through the hull of the old one in the ordinary way. In this case, however, four new zoösporangia had formed within the hull of the original one. The hulls of these sporangia were still held together and attached to the main branch or filament of the fungus but were empty. A small part of the contents was left in the third one that was newly formed. The old zoösporangial cavity contained the upper parts of the new sporangia that had grown through it.

In another instance a single tube had grown up through the old sporangial cavity in the usual fashion. On the end of the tube which projected through the original apical opening of the old zoösporangium, a large, round swelling was present which resembled as to form and size the ordinary oögonia. This departure from the usual behavior of the formation of zoösporangia is shown in Figure 2. The further de-

* Pfeffer, W., Physiology of Plants, 1903, p. 39.

† Pfeffer, W., l. c., p. 116.

[1] Pfeffer, W., l. c., p. 117.

[2] Pfeffer, W., l. c., p. 208.

[3] Klebs, Jahrb., f. Wiss. Bot., 1899, Bd. 38, p. 571.

[4] De Bary, Vervil. Morph. u. Biol. des Pilze, 1884, pp. 356-370.

[5] Pfeffer, W., l. c., Vol. 3, 1906, p. 348.

[6] De Bary, Comp. Morph. and Biol. of the Fungi, 1887, p. 375.

[7] De Bary, l. c., p. 375.

velopment of this structure was not followed out owing to the breaking down of the material under observation.

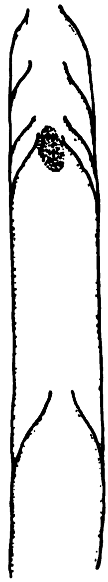

Fig. 1. Saprolegnia showing four sporangia that have grown up in the old zoosporangium x 520.

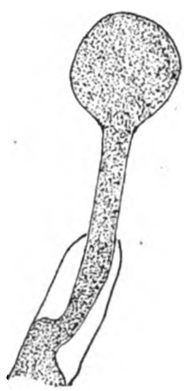

Fig. 2. Hull of the old zoosporangium occupied by a tube having a large terminal swelling x 520.

VAUCHERIA.

F. M. ANDREWS.

In Vaucheria the branches are rather long in proportion to the main part of the plant in some cases, and in other instances rather short in this respect. The plant branches at various angles. In most of the species of Vaucheria in the vegetative parts this is less than a right angle as regards the facing surfaces of the main filament and its branch. A reproductive branch generally starts off at right angles to the main filament and can be recognized as a branch that will produce reproductive organs on this account. They may become at times somewhat less or greater than a right angle, according to circumstances.

The irregular branching is conspicuous in all the different species of Vaucheria except one. This exception is seen in Vaucheria tuberosa, which branches dichotomously.[1] The single tubular cell which is often much elongated may sometimes reach a length of 30 cm.[2] The water forms are generally longer than species that are to be found growing on the soil and in many cases also of a coarser nature. Since it grows frequently in tufts, especially the forms in running water, the length and extensive branching of the mass is often not at first so evident.

In the formation of the large zoöspores the end of the filament is cut off from the rest of the plant by a transverse wall. After a time, depending on conditions, the contents of the single large cell thus formed rounds itself and later escapes through the end of the cell as a single large zoöspore. Sometimes attempts to cause these zoöspores to form by flooding the plants with water, as in the case of the land forms, is very successful, but at other times this process is not attended by very great success or none at all.

The function of the above-mentioned large cell to form the large zoöspores which will reproduce the plant asexually, even though formed in the usual way, does not always do so, owing to changed or unfavorable conditions. Instances of this kind can occasionally be seen in plants that have been submerged. One unusual instance was observed by the writer as is shown by the accompanying Figure 1. The terminal cell, which was cut off in the usual way, was of normal size and shape and apparently was vigorous in every respect as was the rest of the plant. The figure here given was drawn by the aid of a camera a short time after the specimen was observed, from fresh material which had been gathered one hour before.

The unusual feature about this cell was the production of two branches from the sides. These branches were probably of different ages, as both seemed to have had equal opportunity for growth. It will be seen, however, that the branch nearest the apex of the cell is longer than the one near the base of the cell and near the transverse

[1] Sachs, J., Lehrbuch der Botanik. Vierte Auflage, 1874, p. 273.

[2] Sachs, J., l. c., p. 273.

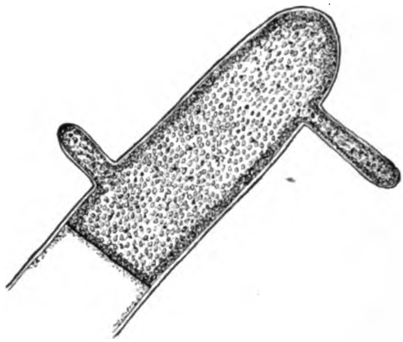

Fig. 1. Zoosporangium of Vaucheria sessilis with two branches x 300.

wall. Neither branch was separated from the supporting cell by a wall, as will be seen from the figure, nor later on, although the specimen was kept and observed under as favorable conditions as was possible. It will be noticed, furthermore, from the figure that the above-mentioned branches extend at right angles from the cell. This recalls the way previously described in this paper in which the branches which are to become or to carry the sex organs in this plant arise.

Trillium Nivale.

F. M. Andrews.

In the year 1898 the writer transplanted twenty specimens of Trillium nivale from the "North Pike" road, about one mile north of Bloomington, to his yard. The purpose of this was to be able to study more conveniently certain structural features and observe as closely as possible the period of anthesis over a series of years.

A study of the habitat was made and all of the observed conditions as to soil, shade and other factors were duplicated closely. It was necessary to protect the plants at first by a low box frame, but the sides of this box stood at some distance from the plants and afforded no more shade to the plants than the rocks which originally surrounded the place from which the plants were taken. This distance between the plants and the sides of the box is evident to some extent in the

Fig. 1. Photograph of part of bed of Trillium nivale.

accompanying photograph (Figure 1). This photograph shows only one corner of the box and was taken five years after the transplanting had been done.

The box was four feet square, made of one-inch poplar lumber, was twenty-five cm. deep and had no bottom. It was found necessary later on to protect the plants at times by galvanized iron wire netting having meshes about one-half cm. square.

The transplanting was done in early spring, care being taken to

remove with each plant or cluster of plants a large mass of the soil in which they were growing. The early blooming of Trillium nivale is well known. This often takes place before the snow has left the ground. The warmth generated by the plant at times melts the snow away in the form of a small well about the plant and entirely to the ground. The plants which were transplanted in the way indicated above finally grew very densely, as shown by Figure 1, and the earliest bloomers melted the snow in large areas. Being able to follow the course of development more closely and conveniently when planted in the box, it could easily be seen that sufficient warmth was generated by the young plants as soon as they had broken through the soil to melt the snow, which was often present to some extent, although this melting was not evident at all times on the surface. On removing the top layers of snow a dome-shaped space over and about the young plant of considerable extent was usually to be found.

In the part of the box shown in the protograph (Figure 1) between fifty and sixty plants in bloom may be seen by a careful count. This photograph represents about one-fourth of the whole area of the box. The blooming plants were fully as numerous all over the interior of the box as in the part shown in Figure 1. This would amount to something over two hundred blooms which had been produced by the original plants and by new plants which had grown since the first ones were planted.

Two of the plants were observed to have advanced the growing end of the rhizome considerably during the first ten years. This amounted to a movement of fifteen cm., or an average of 1.5 cm. per year. The rhizome, however, did not increase apparently in total length from the time of transplanting, since as it advanced at the growing end it died away at the other end and thus maintained about an even length. This agrees with the mode of life of many other similar subterranean plant structures.

These plants seem, although densely crowded, to have continually and rapidly increased for the first ten years. Since then and during the last five years the average increase in number has been small. The number of individuals, although still vigorous, seems to have become so great that all the available space for more individuals to grow in the space offered by the box has been reached and a balance in this respect established. The plants are all equally illuminated and all the other conditions equally favorable for all. It will be noticed in Figure 1 that the plants of equal age show differences as to size. Especially in some individuals the photograph shows a decided difference in the size of the flowers. This difference is, however, only slightly more pronounced than the writer has observed on the average on equal counts of individuals made in the field and under the original conditions.

The density as to numbers of individuals rarely if ever equals that shown by Figure 1 over the same area in the original habitat. A few individuals may, of course, come up close together, but this is only for a very few specimens, while an equal number as that shown by Figure 1 would be scattered over a much larger area, since much more space is available in all directions. This plant in its native habitat shows a

preference not only as to soil and as to illumination, but also as to drainage. This, as indicated above, was taken into consideration in arranging the plants shown in Figure 1.

The blooming of Trillium nivale is not confined to the space of a few days, but in its native habitat, and as shown by the study of the plants partly illustrated by Figure 1, this period of blooming extended often several weeks, according, in part, to the condition of the weather, etc. The period of blooming was shortened by mild weather. The plants I transplanted showed a tendency to begin blooming somewhat earlier as a rule than those in the field, but this was slight.

Pollination was effected by bees which swarmed at times about the flowers, visiting first one and then another continuously. In this way an exceptional opportunity was afforded to watch in a small space and on numerous individuals the way the large amount of pollen was transferred from one flower to another. One insect in this way often visited a half score of flowers in a few minutes, so that the distribution of the pollen was thoroughly done. The pollen is produced in large amounts in each flower and the cells of the anther which open lengthwise down the margin allow the pollen to be puffed out somewhat and made easy of attachment to the visiting insect.

In only a few instances was there any tendency toward a monstrosity in Trillium nivale. This occurred in the transplanted specimens and was evidenced by a partial transformation of the petals in one of the flowers to leaves. This instance of phyllody in Trillium nivale, however, seems to be extremely rare and is all the more surprising when it is remembered that the genus Trillium is rather inclined to monstrosities in instances of phyllody in various of its species. The writer has called attention to some of these monstrosities in a former paper[1] on three of the species of the genus Trillium, namely, Trillium sessile, Trillium recurvatum and Trillium erectum. These three species seem to be more susceptible to variation in this respect than is Trillium nivale. This one case of phyllody during the twenty-three years these plants of Trillium nivale have been under direct observation and where from twenty-five flowers at first to about the two hundred flowers which were produced in 1921 shows that this tendency is rather unusual in this species, when successive yearly observations over a long period and finally in large numbers gave ample opportunity for its detection.

The pollen grains are nearly round and in surface view show short, blunt, numerous points about evenly distributed over the surface (Plate I, Figure 1). They germinate readily in solutions consisting of 3% cane sugar to which is added 1½% of gelatine. In such a mixture germination takes place to a considerable extent after two hours. This is shown in Plate I, Figure 2, where the pollen tube has attained a length of about three times the diameter of the spore. After three hours the pollen tube has grown to about four times or more the diameter of the spore on the average, and as a rule is considerably more irregular in outline, Plate I, Figure 3.

[1] Andrews, F. M. Proceedings of the Indiana Academy of Science, 1905, pp. 187 and 188.

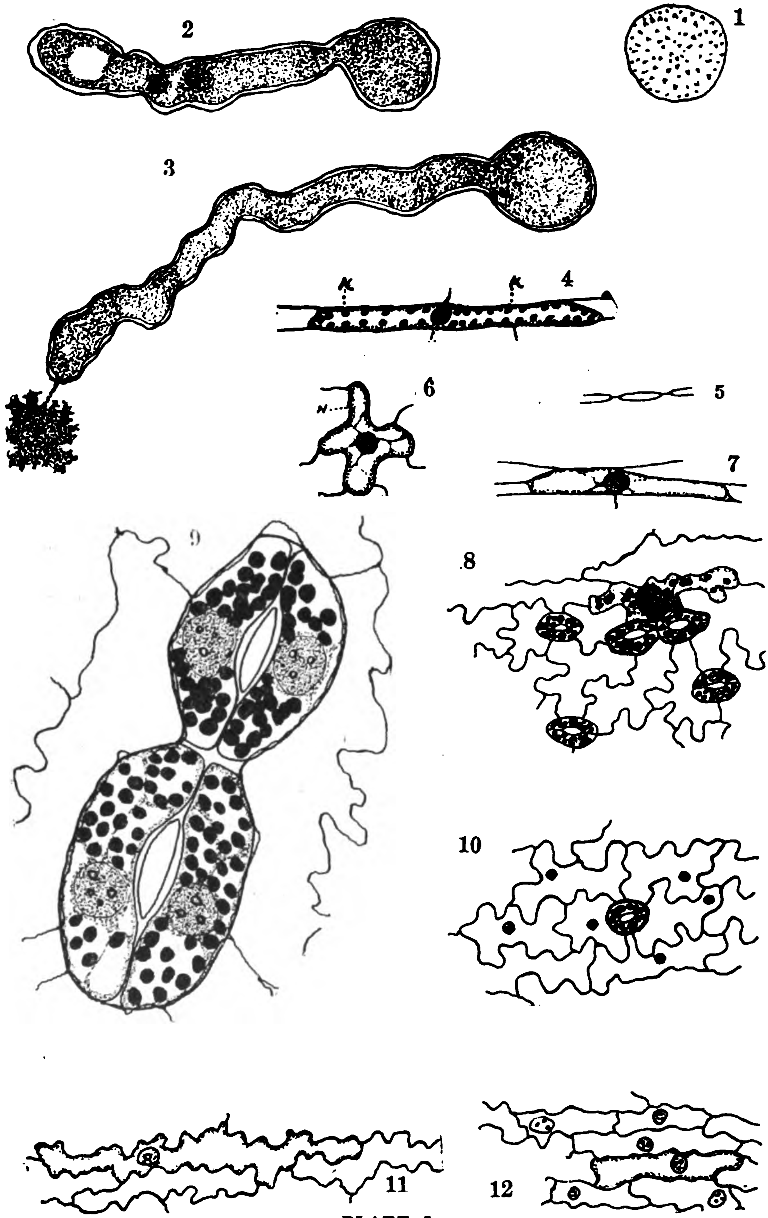

PLATE I.

At times when this length of pollen tube has been reached, it bursts, this always taking place at the end and often with considerable force so that the contents is generally forced out through a small pore and in a small stream (Plate I, Figure 3). The contents then collects as a ragged edged-mass at the end of the small stream of contents whose length is controlled by the force of expulsion, which is generally sufficient to force out the stream of contents to a length about equal to the diameter of the pollen tube (Plate I, Figure 3). When placed in distilled water the pollen grains of Trillium nivale frequently explode at once and apparently with considerable force, considering the size of the grain. This, of course, is due, as is known of some other kinds of pollen grains, to a rather sudden increase in the hydrostatic pressure of this cell. This, however, occurs in Trillium nivale as a rule in an unusually short period of time. Movement of the protoplasm of the pollen tube, as in Plate I, Figures 2 and 3, may often be seen.

The elongated epidermal cells of the stem are often filled with red colored sap and, partly due to rapid growth, have unusually thin outer walls for cells in such a position (Plate I, Figure 4). The nucleus is large in proportion to the size of the cell and several nucleoli are usually present. The red cell sap, when present, partly conceals the chlorophyll granules. The lateral walls of the epidermis even though very thin are provided with shallow pits (Plate I, Figure 4 K), which can just be observed when magnified 300 times. These pits, which are often seen in the walls of internal cells of many plants, are brought out with great definiteness when magnified 1,060 times. They are then observed to have rounded edges and are rather broad (Plate I, Figure 5 K).

The cells of the epidermis from the upper side of the leaf of Trillium nivale are wavy in outline and show no stomata. A slow movement of the protoplasm can generally be seen under favorable conditions in the various strands. The nucleus which is sometimes about central and sometimes parietal is rather large and shows in many cases several nucleoli (Plate I, Figure 6). Pits in the walls, as at H, Plate I, Figure 6, are barely discernible when magnified 200 times. The cells from the midrib on the upper side of the leaf of Trillium nivale show, as would be expected, a decided elongation and reduction in diameter. A large nucleus and rather actively moving protoplasm at times are generally much in evidence, the latter especially when magnified 450 times (Plate I, Figure 7).

The lower epidermis of the leaf of Trillium nivale shows, as usual, the presence of stomata. The chlorophyll granules are very few in number, but active movement of the protoplasm is often evident. The nuclei are rather large, often nearly equalling the diameter of some of the cells. The stomata, which are present on the lower surface of the leaves exclusively, are generally arranged so that one communicates with a respiratory cavity. Some departures from this arrangement are, however, present, as when two stomata are over one respiratory cavity as is shown in Plate I, Figure 8. The writer has shown this to be the case in a former paper.[1] In the paper referred to, the history and

[1] Andrews, F. M. Proceedings of the Indiana Academy of Science, 1914, pp. 209-211.

literature on this subject are given and the same peculiarity in some other plants is noted. As indicated in that paper, interesting questions concerning the location, development, and reactions of the supernumerary stomata await solution.

The outer epidermis of the sepal frequently shows twin stomata over one respiratory cavity[2] (Plate I, Figure 9). The strands of protoplasm often showed movement for 24 hours when magnified 450 times. The inner epidermis of the sepal, as the outer epidermis, has very wavy walls, but more pronounced than the outer epidermis in this respect (Plate I, Figure 10). Stomata are present, but few in number. In these cells the movement of the protoplasm often continued for as much as six hours during observation, as could be easily seen with moderate magnification.

The epidermis from the outside of the petal of Trillium nivale showed, as usual, much elongated and narrow cells and with very wavy thin walls (Plate I, Figure 11). The epidermis from the inner surface of the petal has smaller cells than those of the outer epidermis, its cell walls are much less wavy and more delicate (Plate I, Figure 12).

The above-mentioned facts coincide closely with similar observations made on specimens of Trillium nivale which were obtained from the native habitat. Certain other points, such as some of those above referred to, deserve further study, which can best be carried out under the conditions described in this paper.

EXPLANATION OF PLATE I.

All of the figures of this plate are of Trillium nivale.

Fig. 1. Pollen grain, surface view x 300.

Fig. 2. Pollen grain after two hours in three per cent cane sugar plus one and one-half per cent gelatine x 300.

Fig. 3. Pollen grain after three hours in the solution used for the grain shown in Fig. 2 x 300.

Fig. 4. Epidermal cell from stem x 300.

Fig. 5. Piece of cell wall of cell illustrated in Fig. 4, showing pits at K enlarged x 1060.

Fig. 6. Cell from upper epidermis of leaf showing pits at H x 300.

Fig. 7. Cell from midrib of upper epidermis of leaf x 100.

Fig. 8. Few cells from lower epidermis of leaf x 100.

Fig. 9. Twin stomata from outside of sepal x 520.

Fig. 10. Few cells from inner epidermis of sepal x 100.

Fig. 11. Epidermal cells from outside of petal x 100.

Fig. 12. Epidermal cells from inside of petal x 100.

[2] Andrews, F. M. Proceedings of the Indiana Academy of Science, 1914, pp. 209 and 210, Fig. 1.

SPIROGYRA.

F. M. ANDREWS.

A number of instances are on record where irregularities occur as to the form, conjugation or general behavior in the genus Spirogyra. Among these may be mentioned a paper by Gregory[1] which illustrates a number of specimens of Spirogyra which show branches given off. In one instance a figure is given showing a branch which has itself divided into two branches. See Fig. 2 of Gregory's paper. This, as the author states, is due probably to monads. Attention is also called to the well-known galls of Vaucheria and of Oscillatoria, the latter due to the entrance of zoöspores of Chytridiae. In the Spirogyra cells which branch, as Gregory shows, these all proceed from the convex side of the cell. This appearance of these branches on the convex or stretched side of the Spirogyra cell recalls a similar disposition in the arrangement of roots on the convex side of the main root, which, however, in the case of the roots, is a response to the mechanical factors that are operative.

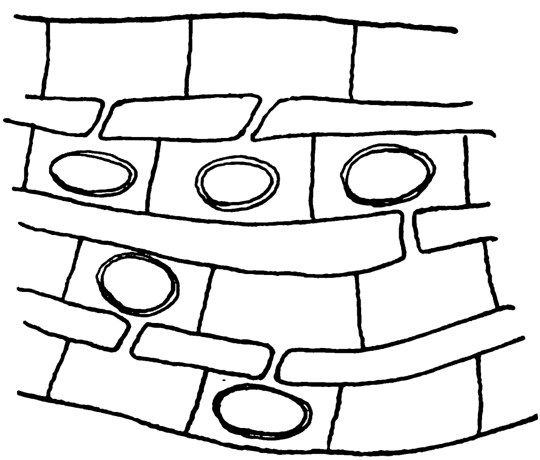

Fig. 1. Spirogyra crassa x 300.

A paper by the writer[2] in 1910 showed conjugation in two different species of Spirogyra, as Spirogyra crassa and Spirogyra communis. In another paper[3] I have called attention especially to the question of irregular cases of conjugation in Spirogyra.

In this paper also the literature is referred to in so far as it pertains to the topic under discussion. Chief among these was the paper

[1] Gregory, Emily L. Bulletin of the Torrey Botanical Club, 1892, Vol. 19, pp. 75-79.
[2] Andrews, F. M. Bulletin of the Torrey Botanical Club, 1910, Vol. 38, p. 299.
[3] Andrews, F. M. Proceedings of the Indiana Academy of Science, 1912, pp. 89-91.

of Tröndle,[1] who mentions a rather unusual case of irregular conjugation. An instance of deviation in form is shown in a paper by Pickett.[2] Another instance is given by Weatherwax of branching, etc., under the conditions there numerated. So far, however, as the branching of

Fig. 2. Spirogyra elongata x 400.

Spirogyra is concerned, this has been known for many years.

As Sachs[4] says, if one cuts up the long filaments of Spirogyra and the pieces are laid on wet peat, some of the cells put out branched colorless tubes, which behave like roots. In fact, somewhat similar results take place, as Sachs says, in highly organized plants, as in the rooting of several shoots in many vascular plants; and the stimulus of contact in the development of structures, as in Cuscuta. So that branching may be produced in Spirogyra not only from a diseased condition but also at times by injuries.

The writer has observed another case of somewhat more compli-

[1] Tröndle, A. Ueber die Kopulation und Keimung von Spirogyra, Botanische Zeitung, 1907, Bd. 65, p. 192.

[2] Pickett, F. L. Bulletin of the Torry Botanical Club, 1912, Vol. 39.

[3] Weatherwax, Paul. Proceedings of the Indiana Academy of Science, 1914, pp. 203-206.

[4] Sachs, J. Vorlesungen über Pflanzen Physiologie Zweite Auflage, 1887, p. 40.

cated conjugation in Spirogyra than the one referred to in the paper above mentioned. This material formed a sort of net on the water. When examined it showed not only some further examples of the deviations in conjugation mentioned in the paper just cited, but also a few more complicated cases of what I term net conjugation on account of several filaments being held together in the process. Being associated often in such dense masses, it is really not so surprising that such examples of conjugation would occur, but rather we should have the right to expect that it would be more frequent than has heretofore been reported. Figure 1 gives a picture of one case. This figure is a camera drawing and, as will be seen, four filaments are concerned in the process.

Another deviation from the ordinary is shown by Fig. 2. This is also a camera drawing. The material was obtained from the same place as that from which Fig. 1 was made. Most of the Spirogyra in the water where this material was obtained was Spirogyra elongata, but there was also a considerable quantity of Spirogyra communis and Spirogyra crassa. In a few instances some cells were observed where the number of chloroplasts varied. As shown in Fig. 2, a few of the cells had two chloroplasts, whereas the usual number of chloroplasts is one.

Some Aspects of Stone Mountain and Its Vegetation.

Elmer Grant Campbell.

Stone Mountain is a huge dome-shaped rock, situated sixteen miles east of Atlanta, Georgia. It measures seven miles in circumference at its base and rises 686 feet above the adjacent land surface. This mighty stone includes 663 acres of exposed granite area.[1]

The purpose of this paper is to give a panoramic view of Stone Mountain and its remarkable vegetation.* This view is prefaced by geological and botanical notes from some of the literature relative to the subject.

Geology.

Dr. Thomas L. Watson has set forth an invaluable collection of data concerning the geology of this most wonderful stone,[1] a small portion of which follows:

"Stone Mountain forms one of the few conspicuous, unreduced, residual masses found rising above the general surface-level of the Georgia Piedmont Tertiary peneplain. That this and the adjacent masses of hard contorted granite-gneiss, in the Lithonia area to the south, were not reduced to the same approximate level of the surrounding plain, can be readily accounted for, by differential rock-hardness, and remoteness from the major streams in the region. . . . .

"The chemical composition of this granite mass is shown in the two following analyses made by Mr. R. L. Packard in the laboratory of the Survey from specimens collected by Professor Yeates from the Hayne quarry:

	I	II
Silica	72.56	71.62
Alumina	14.81	16.05
Iron oxide	0.94	0.86
Lime	1.19	1.07
Magnesia	0.20	0.17
Soda	4.94	4.66
Potash	5.30	4.92
Ignition	0.70	1.00
Total	100.64	100.39

I. Analysis of the perfectly fresh rock.

II. Analysis of a spawl, which was exposed for three or four years on the dump-pile at the quarry. . . . .

"Physical tests made on the Stone Mountain granite yielded the following figures:

Specific gravity	2.686
Weight of one cubic foot of stone expressed in pounds	167.90

[1] Bulletin 9A Geological Survey of Georgia.

* The study was made in September, 1916.

Number of cubic feet of stone contained in one ton (2,000 pounds)	11.9
Percentage (ratio) of absorption	0.067

"Crushing strength tests made on the granite, in two-inch cubes, gave the following results:

	Strength in pounds	Strength in pounds per sq. in.
Stone Mountain, Ga	85,000	21,250
Stone Mountain, Ga	50,325	12,581
Stone Mountain, Ga	48,760	12,190
Stone Mountain, Ga	65,610	16,402

"A similar series of strength tests, made in 1890 at Purdue University, gave 12,438, 14,425, 12,904, 13,406 and 12,726 pounds per square inch."

Botany.

Dr. H. W. Ravenel in the Bulletin of Torrey Botanical Club, June, 1876, gave an interesting note, as follows:

Rudbeckia Porteri.—"I found this species in 1848 at Stone Mountain, Georgia, growing abundantly on the ridges and top of the mountain with Quercus Georgiana. Professor T. C. Porter had just preceded me in its discovery and the uncertain genus was dedicated to him. I have never heard of it anywhere else."

"The outlying granite peak in middle Georgia seems to have an interesting Flora. I found a well-marked variety of Hypericum prolificum and Mr. Canby has since (in 1869) found a new species of Isoetes growing in shallow pools on the summit."

Dr. John K. Small in several numbers of the Bulletin of the Torrey Botanical Club of the year 1894 made references to the plant life of Stone Mountain as follows:

January, 1894. "*Asplenium Bradleyi.*—Contrary to its usual habitat, which is perpendicular or overhanging and rather damp disintegrating cliffs. Asplenium Bradleyi was found growing on horizontal moss-covered granite rocks at the northern base of Stone Mountain, De Kalb County, Georgia, in April, 1893, altitude 1,000 feet."

"*Amorpha virgata.*—Found only on the northern and western slopes of Stone Mountain * * * Fruiting in July. It is apparently restricted to a narrow belt ranging from 1,100 to 1,200 feet above sea level and grows in a few places where the granite rocks are flat enough to hold a layer of sand."

"*Amygdalus Persica* L.—During the past season it was noticed at numerous localities in middle Georgia and was collected on the dry, rocky slopes of Stone Mountain * * * early in July at an altitude of 1,200 feet, well established and producing abundant fruit."

"*Nyssa biflora walt.*—Grows on the very summit of Stone Mountain * * * altitude 1,686 feet. It is remarkable that this tree usually confined to the seacoast or seaboard from southeastern Virginia southward should occur in the above situations. There are a number of trees on the small dome-like top of the mountain and they seem to flourish although somewhat worn and torn by heavy winds which sweep by their exposed habitat and thrive notwithstanding the fact

that they grow in but a few inches of sand collected in depressions of the granite rock.

"*Lagerstroemia Indica L.*—The species is now well established about Stone Mountain * * *."

"July, 1894. *Cuscuta arvensis.*—Grows about the base of Stone Mountain, Georgia, in mats on Gymnolomia Porteri where this species forms dense patches."

Dr. Roland M. Harper, in the Bulletin of the Torrey Botanical Club, August, 1901, reported plants found on or near Stone Mountain as follows:

Antennaria calophylla Green.
Lomicera flava sims.
Opuntia vulgaris mill.
Polygala Curtissii Gray.
Juncus Georgianus Coville Small.
Scirpus sylvaticus L.
Asplenium angustifolium."

At present it is hardly possible to view the plant distribution of this unique mountain without feeling the spirit of these botanical notes. One imagines he sees the same "dense patches" of Gymnolomia porteri, and the "Amorpha virgata" on the little shelves of accumulated sand; and the same "Nyssa biflora" in its extremely strange anchorage on the summit, growing in company with ancient and weater-beaten specimens of Juniperus virginiana, and the same assemblage of "Rudbeckia porteri" grouped with their more rugged associates "Quercus Georgiana" situated high up toward the top of the mountain; and no doubt some of the woody individuals standing here today were standing here a century ago, and to be sure the herbaceous species beheld now, have beauties and habits similar to the beauties and habits of their ancestors in generations past when botanists and nature adorers beheld them and loved them and praised them.

Physical Features and Tree Distribution.

The geological notes cited above indicate the chemical constituents and the physical durability of this granite dome of nature. It stands as a physiographic marvel, a figure unique among the geological curiosities of the world.

It may be interesting to note, that today plant life is one of the most powerful natural forces operating against the eternal existence of this mountain.

The North Side—Here almost the entire area stands like a stone wall perpendicular to the adjacent plains at the base, but this granite face bends gradually inward towards the crest, giving an oval outline to the mountain as viewed from the north. (Fig. 1.) The surface is unbroken and void of phanerogamic vegetation. The waters of all the regional rain storms that have beaten upon this mighty rock through untold ages have rushed unhalted down its sides, and yet the most marked physical features on the extreme north are numerous clean streaks, some of which are several feet in width, extending from summit to base. On close examination these streaks are found to be extremely shallow and perfectly beveled furrows in which no lichens are

Fig. 1. A view of the steep bare north side of Stone Mountain and the pure broad leaf forest on the narrow talus at the base.

Fig. 7. A mixed forest southeast of Stone Mountain.

growing. One might fancy these as the ravines on the north side of Stone Mountain that a million years or more have wrought.

In these clean, shallow grooves, or water courses, the pure, light grey granite is exposed, while the areas between them are covered with lichens of a dark grey color. This gives the north side a striated aspect.

Fig. 8. A pure stand of Andropogon virginiana on the northwest side of Stone Mountain and dwarfed red cedar in the background.

The vertical north side merges westward into a graded slope the surface of which becomes progressively less steep and more broken toward the west, and thence, on around to the south. On the eastern portion of this slope no flowering plants are found, except in depressions or around weathering fragments of granite. Further west, however, there is a meager forest associated with a limited number of herbaceous species (Fig. 8). The north talus broadens as it extends westward and for a considerable distance the tree formation is dense, composed purely of broad-leaved species (Fig. 2).

Fig. 3. A south side view near the crest where the tree growth is composed largely of red cedar and loblolly pine.

The South Side—The surface of the south side is broken and irregular, having a general slope of about 45 degrees. Near the summit the tree growth is spare, red cedar and loblolly-pine being practically the only species found. About midway from top to base pine is the only

Fig. 4. A view about half way to the summit on the south side of Stone Mountain. showing the broken surface and the uneven distribution of the vegetation. Broom-sedge (Andropogon virginiana) in one of the few cracks of the mountain.

Fig. 5. A pure stand of pine at a high elevation on the south side.

woody species, all the trees being scrubby and very much dwarfed. The south talus, however, is densely covered by a pure stand of pine, each tree having a remarkably long and clear bole.

Figures 3, 4, and 5 give a progressive view of the forest on the south as it spreads from summit to base. On the south side of Stone Mountain, in fact on all parts except the extreme north side, the topography is unique, and the landscape is unsurpassed in grandeur.

Deep forested ravines (Fig. 7), cedar trees a century old or more (Fig. 3), tumbled heaps of massive granite blocks (Fig. 5), garden-like shelves of accumulated alluvium, radiant and fragrant with flowering plants (Fig. 9), cracks in the exposed granite filled with growing Andropogon virginiana (Fig. 4), a broken, scaly, cracking, wavy surface, all tell a tale of dynamics contrary to the static north side with its mere clean, light grey streaks alternating with the dark grey lichened areas.

Fig. 2. A view on the northwest side of Stone Mountain. The almost bare slope is gradual and the somewhat broad talus supports a pure stand of broad leaf trees.

Fig. 9. A pure stand of Gymnolomia Porteri in full bloom, on the south side of Stone Mountain.

The sun's rays have always struck Stone Mountain in such a way as to make the summer temperature abnormally high on the south side and abnormally low on the north. In like manner the sun's rays make the disintegrating effects of the short winters abnormally great on the south (frequent thawing and freezing) and abnormally small on the north (less frequent freezing and thawing). Thus Stone Mountain has, in close proximity, virtually two climates and two types of topography, and under these physiographic and climatic differences two remarkably diverse floral types have developed.

The East and West Sides—The east and west surfaces are strikingly similar, each having a slope which seems to be about a mean between the steep north and the gradual south, and a tree formation of near a half and half mixture of deciduous broad leaf and coniferous evergreen (Figs. 6 and 7).

Fig. 6. Mixed forest on the west side of Stone Mountain.

General Distribution of Plants.

Based on tree distribution, as an index, the general vegetation of Stone Mountain may be grouped as follows:

I. Pure Deciduous Broad-leaved on the North Side.

Here woody specimens were collected and identified as follows:

Castanea dentata.
Cornus florida.
Diospyros Virginiana (Fig. 1)
Fraxinus Americana.
Hamamelis Virginiana.
Vitis rotundifolia.
Vaccinium arboreum.
Carya glabra.
Kalmia latifolia.
Liquidamber Styraciflua.
Styraciflua.
Liriodendron Tulipifera.
Magnolia acuminata.
Nyssa sylvatica.
Oxyodendron arboreum.
Quercus alba.
Quercus Georgiana.
Quercus prinus.
Cornus stolonifera.

Associated with this group of woody species is a typical herbaceous flora, but here, as might be expected, in September the landscape presents an aspect of quiet and maturity rather than one of blossom and vigor, and the fragrance of spring time have given place to such inviting odors as the ripened fruit of the muscadine, whose drooping ladened boughs hang from many a tree and crown almost every rugged clump of granite debris. A small number of herbaceous specimens were taken and identified as follows:

Clitoria mariana.
Lespedeza frutescens.
Desmodium Dillenii.
Desmodium paniculata.
Silene stellata.
Asplenium Bradleyi.
Asplenium angustifolium.
Solidago odora.
Aspidium marginale.
Pteris aquilina.

The following mature spring blooming plants were observed in abundance:

Violets.
True Solomon's Seal.
False Solomon's Seal.
Composites of various kinds.
Legumes.
Mints.
Honeysuckle.

II. Pure Coniferous Evergreen on the South Side.

Here the tree list is notably short. Pinus Taeda and Juniperus Virginiana. This so-called pure evergreen forest is slightly diluted by the following deciduous species: Nyssa sylvatica, Quercus prinus, Quercus Georgiana.

The talus on the south is covered by a pure stand of Pinus Taeda. This pure stand grades inland into a mixed forest with a herbaceous flora more or less like that found in any broad leaf forest of the region. The herbaceous vegetation of the exposed areas on the south

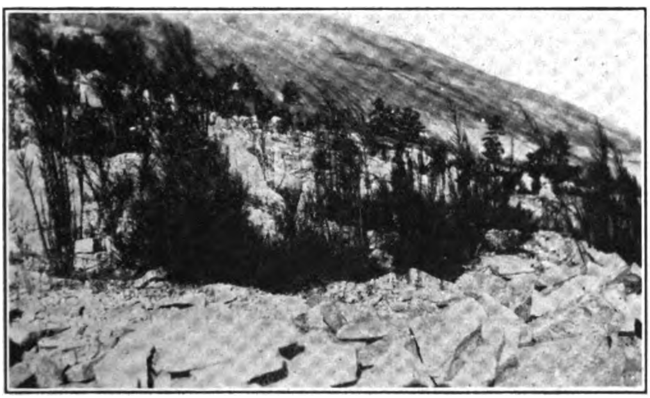

Fig. 10. Eupatorium capillifclium growing in the pure granite debris of the quarry on the southeast side of Stone Mountain.

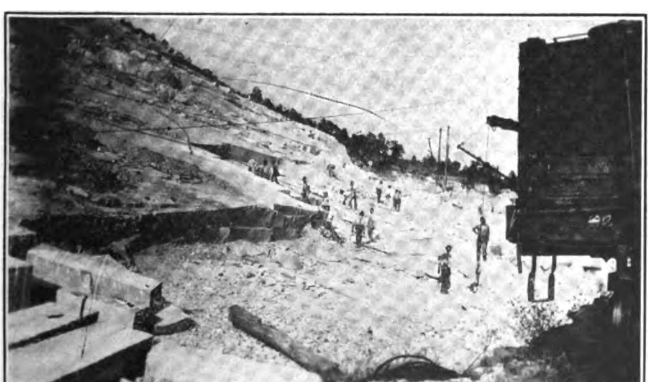

Fig. 11. Quarry on the east side of Stone Mountain.

side, however, is composed almost wholly of three species: Andropogon virginiana (Fig. 8), Solidago odora, Gymnolmia Porteri (Fig. 9).

III. The Mixed Forests on the East and West Sides.

On these areas there is a general mingling of the north side vegetation with that of the south, but in this mingling there is a notable absence of certain of the north talus species and the occurrence of certain species not found on the north or south.

Pycnanthemum albescens.	Amorpha virgata (small).
Liatris polyphylla.	Prunus Persica.
Eupatorium capillifolium (Fig. 10).	Hypericum prolificum.

are species more or less peculiar to the east and west sides.

SUMMARY.

In the study of plant ecology on Stone Mountain, certain rather remarkable conditions have been noted.

1. The north side is a vertical unbroken wall whose face is beveled toward the summit, and is only partially covered with lichens, its only form of vegetation.

2. The rich narrow talus on the north, which must have been formed by a very remote falling of granite fragments from the summit, bears a dense forest of broad-leaved trees with a typical herbaceous association.

3. The south side surface stands at an angle of about 45 degrees and is sparsely overgrown with conifers and flowering herbs.

4. The broad talus on the south is covered by a pure stand of pine merging into a mixed forest toward the outer margin, where are found many broad-leaved deciduous species, as oaks, hickories, tulip, sweet gum, black gum, and a herbaceous formation approaching in character that found in a pure regional deciduous forest.

5. The east and west slopes seem to be a mean between the steep north side and the gradual south side, and the east and west floras are partial blends between the north and south floras.

CONCLUSIONS.

1. A steep north side and a gradual south side have been made possible by certain conditions of the past, viz., differential exposure to the sun's rays, prevailing winds, and proximity to major streams.

2. The same conditions that have produced a physiographic distinction between the north and south sides have also made possible a floral distinction.

3. The physiographical and vegetational aspects of the east and west are but natural blends between the extremes of the north and south.

Purdue University.

Plants New to Indiana. X.

Charles C. Deam.

Specimens of all of the plants referred to in this paper are deposited in the Deam herbarium. The grasses were determined by Agnes Chase. The Carices were determined by K. K. Mackenzie. The determinations of the remainder have been checked by specialists in the respective genera.

Muhlenbergia capillaris (Lam.) Trin.

Harrison County, October 7, 1921. No. 35257. Rocky, wooded slope about three miles east of Elizabeth. This open wooded slope borders the road in its descent over the bluff to the Ohio River. Growing in tufts in hard ground, closely associated with Quercus velutina, Viburnum rufidulum, Smilax bona-nox, Agave virginica, Liatris scariosa, Andropogon scoparius, Allium cernuum and many others.

Sporobolus clandestinus (Spreng.) Hitchc.

Fulton County, September 14, 1921. No. 34717. On a roadside sandy knoll two and a half miles northeast of Leiter's Ford. Marshall County, September 14, 1921. No. 34762. On a roadside sandy knoll just north of Yellow River, about six miles southwest of Plymouth.

Poa Wolfii Scribner.

Jay County, May 14, 1921. No. 33861. On the flood plain of a small rivulet in a white oak woods about eight miles northeast of Portland. Closely associated with Quercus macrocarpa, Ulmus americana, Fraxinus nigra, Aesculus glabra, Phlox divaricata, Claytonia virginica and others.

Carex aggregata Mackenzie.

Franklin County, May 17, 1921. No. 33972. Low alluvial bank of the west fork of White Water River two miles south of Laurel.

Carex gravida Bailey.

Fayette County, May 16, 1921. No. 33931. On the low bank of the old canal about one mile south of Connersville. Associated with Phacelia Purshii.

Smilax bona-nox Linnaeus.

This species has the base of the stem covered more or less with a dense stellate pubescence. I found the first specimens of this species in 1915 on the wooded bluff of the Ohio River in Crawford County near Leavenworth. I was not able to determine it to my satisfaction, so I set to work to find other locations for this species and collect in quantities until I had over a hundred specimens. I have found also a few specimens on the VanBuren Ridge in Perry County, about seven miles east of Cannelton. It is frequent in Harrison County on the bluff of the Ohio River east of Elizabeth.

Sisyrinchium atlanticum Bicknell.

Cass County, June 7, 1916. No. 20152. Abundant in sandy soil on the south side of Lake Cicott. Lake County, June 5, 1916. No. 20112. In a wet prairie habitat along the railroad just south of Shelby. I also have a specimen collected in the same county by L. M. Umbach, June 19, 1897, from a meadow near Miller. Stark County, June 1, 1916. No. 19913. On the low, sandy border of the southeast side of Bass Lake.

Corallorrhiza Wisteriana Conrad.

Decatur County, May 5, 1912. No. 10450. Collected by Mrs. Chas. C. Deam under a beech tree on the bluff of Flat Rock River about three-fourths of a mile above St. Paul. Dubois County, May 4, 1919. No. 27250. In a white oak woods four miles southwest of Huntingburg. Orange County, May 25, 1901, under a beech tree in a woods near Abbey Dell. Perry County, April 24, 1919. No. 27101. Rare on the wooded slope of the bluff of the Ohio River about six miles above Cannelton. Sullivan County, April 16, 1919. No. 26926. In very sandy soil in the Rose woods about one mile south of Grayville. Closely associated with Quercus velutina, Carya alba, Podophyllum and others.

Salix serissima (Bailey) Fernald.

Lagrange County, May 30, 1916. No. 19882. A tree fifteen feet high and three inches in diameter at breast high, in a pond about one mile south of Mongo. Also found along Pigeon River about one mile east of Mongo. Steuben County, July 24, 1906. No. 1251. On the low border of the west side of Silver Lake.

Polygonum neglectum Besser.

Laporte County, September 15, 1921. No. 34841. Along a woods road in a beech-sugar maple clearing about two miles north of Mill Creek.

Lychnis coronaria (L.) Desr.

Elkhart County, July 2, 1921. No. 34410. A colony of about fifty feet long and ten feet wide on the gravelly wooded bank of the St. Joseph River about one and a half miles northwest of Bristol.

Euphorbia Rafinesquii Greene.

Steuben County, August 29, 1920. No. 32533. Roadside near a crossroads about five miles northeast of Angola.

Euphorbia serpens H. B. K.

Dearborn County, September 21, 1919. No. 30122A. On a rocky bar in Wilson's Creek about one mile northeast of Aurora. Closely associated with Euphorbia maculata. Perry County, October 2, 1920. No. 33357. A large prostrate plant, rooting at the nodes, in a cornfield between the road and the Ohio River just east of Deer Creek.

Oenothera pratensis (Small) Robinson.

This is a frequent to a common plant in the southern part of the State. It is especially frequent in the "flats." I suspect that all references to Oenothera fruticosa in southern Indiana should be referred to

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[1] Bul. Torrey Club. Vol. 46:184:1919.

this species. I have it from Bartholomew, Clark, Crawford, Dubois, Gibson, Jackson, Owen, Posey, Scott, Sullivan and Tipton Counties.

Acerates hirtella Pennell.

All Indiana references to Acerates floridana[1] should be transferred to this species. I have specimens from Cass, Elkhart, Jasper, Lake, Laporte, Martin, Newton, Porter, Pulaski, Starke, Tipton, Vigo and White Counties.

Veronica glandifera Pennell.

Pennell[1] has shown that the plants of our area that have been called Veronica Anagallis-aquatica should be transferred to Veronica glandifera. I have this species from Delaware, Elkhart, Grant, Huntington, Jackson, Kosciusko, Montgomery, Noble, Porter, Shelby (Mrs. Chas. C. Deam), Steuben and Wells Counties.

Aureolaria pedicularia ambigens (Fernald) Pennell.

Recent studies of Gerardia (Aureolaria) pedicularia show that Indiana specimens belong to the glandular variety, ambigens. I have specimens from Elkhart, Kosciusko, Lagrange, Lake, Laporte, Marshall, Newton, Porter, Starke and Steuben Counties.

Artemisia ludoviciana Nutt.

Marshall County, September 14, 1921. No. 34761. Common along the railroad and adjoining roadside about one and a half miles southwest of Plymouth.

[1] Torreya Vol. 19:170:1919.

The Toll of Weeds in Indiana.[1]

Albert A. Hansen.

The early settlers in Indiana encountered little difficulty with the weed problem, since few of our native plants are serious weeds. As the land became more settled troublesome weeds began to appear, most of them being European plants that were introduced in impure seed. Since the earliest days of Indiana agriculture, the weed problem has increased in seriousness until at the present time the loss due to the presence of weeds is enormous. Before the weed problem can be solved in Indiana, the farmers themselves must understand and appreciate the seriousness of the situation. An understanding and appreciation of this character can perhaps be secured by a knowledge of the various ways in which weeds cause loss and the amount of damage done.

The extent of the damage caused by weeds is not ordinarily realized. The presence of weeds has been accepted as inevitable and the tendency has been to ignore them. It is hoped that the estimates here presented will not only call attention to the different ways by which weeds cause damage, but that they will also be of value in creating a realization of the importance of the problem. It is a subject that is of importance to all citizens of the state since the welfare of Indiana is largely dependent on agricultural prosperity and the control of weeds is an important factor in profitable agriculture.

The figures herein considered are based on production during the year 1920, even though 1920 can hardly be considered a normal agricultural year. The values of the various farm crops were obtained from the "Year Book of the State of Indiana, 1920."

The final estimate does not include such considerations as the damage to health caused by hay-fever weeds, etc., the losses caused by weeds harboring harmful insects and plant diseases, the esthetic loss, and the reduction in the value of property due to the presence of weeds. On the other hand, the valuable features of weeds such as the value of the organic matter they supply and the prevention of soil washing, are not considered since even approximate estimates of this character are practically impossible to obtain. In preparing the estimates, assistance was obtained from a number of specialists who have devoted many years to the study of Indiana agriculture.

Tillage Loss Due to Weeds—The figures relative to the tillage loss occasioned in cultivated crops are based on work performed in the office of Farm Management, U. S. D. A., demonstrating that cultivation costs about one-sixth of the total value of a farm crop. It is estimated conservatively that one-half of the cost of cultivation is due to the presence of weeds.

[1] Contribution from the Botanical Department (Extension Division) of the Purdue University Agricultural Experiment Station.

Crop	*Value, 1920*
Corn	$119,647,000
Potatoes	8,448,000
Sweet Potatoes	396,000
Tobacco	2,160,000
Onions	1,456,000
Sorghum (unofficial estimate)	738,000
Cabbage	114,000
Broom corn	17,000
Dry beans	91,000
Soy beans (based on 80% of crop cultivated)	97,600
Cowpeas (based on 40% of crop cultivated)	100,800
Total value of tilled crops in Indiana (1920)	$133,265,400
One-sixth of total value (cost of cultivation)	$22,210,900
Tillage loss (one-half of cost of cultivation)	11,105,450

Loss Due to Reduced Crop Yields Caused by Weeds—The presence of weeds has been estimated to reduce the yield of corn 10 per cent; tame hay, 3 to 16 per cent; potatoes, 6 to 10 per cent; spring grain, 12 to 15 per cent; and winter grain, 5 to 9 per cent.[1] The total value of farm crops in Indiana during 1920 was $274,150,000. Assuming that the presence of weeds caused a 10 per cent reduction of crop yields, the loss would be $27,415,000.

Discount Losses—The presence of weed seeds in small grains is estimated to cause an average discount of 1 per cent. The discount may be considered as a measure of the damage due to the presence of the weed seeds. The total value of wheat, oats, barley, and rye during 1920 was $80,272,000, hence the discount loss in these crops was $802,720.

The discount loss caused by weed seeds in clover seed is estimated at 10 per cent. The value of the clover seed crop in 1920 was $1,392,000, hence the discount loss was $139,200. Figures are not available for the value of the grass seed crop during 1920.

The presence of weeds in hay is estimated to cause a discount of 5 per cent. The total value of the 1920 tame hay crop was $49,060,000, consequently the loss was $2,453,000.

The total discount loss can then be figured:

Small grains	$802,720
Clover	139,200
Hay	2,453,000
	$3,394,920

Loss Due to Land Rendered Incapable of Profitable Cultivation—The presence of the Canada thistle, wild garlic and other noxious perennial weeds has made certain areas incapable of profitable cultivation. Although the amount of land abandoned to weeds is not large in Indiana, it is a factor worthy of consideration. Land of this character occurs for the most part as small areas on a number of farms. The

[1] Cates, H. R.—"The Weed Problem in American Agriculture." Separate from yearbook of the Department of Agriculture, 1917, No. 732, p. 3.

total loss from this source is estimated at $100,000. In this connection, it should be remembered that certain otherwise profitable crops cannot be grown on weedy land.

Railroad Weeds—A few years ago the writer obtained estimates of the cost of destroying weeds on the right of way of the principal railroads in the United States. The estimates ranged from $10 to $60 per mile per year. Assuming that it costs $10 per mile per year to destroy the railroad weeds in Indiana, the total annual cost for 15,000 miles of track (both steam and electric railroads) will be approximately $150,000.

Turf Weeds—The damage due to the presence of weeds in lawns is extremely difficult to estimate. Assuming the damage at $2 per lawn per year, the total will be about $200,000. To this should be added the cost of weeding golf courses and miscellaneous turfs.

Roadside Weeds—The time devoted to cutting roadside weeds can be conservatively estimated at one day of labor per farm per year. If but one-fourth of the farmers devote even this small amount of time to their roadside weeds, it will amount to 52,500 days on the 210,000 farms of Indiana. At $3 per day for a man and team, the bill for cutting roadside weeds will amount to $157,500 per year.

Pasture Weeds, Waste Place Weeds, Etc.—The estimated annual cost per farm of clipping stubble land, mowing weedy pastures and cutting waste place weeds is $5 per year. For 210,000 farms the total is $1,050,000.

Miscellaneous Losses—Among the miscellaneous losses may be included the loss from poison plants, damage to milled products caused by wild garlic and similar weeds, damage to dairy products due to wild garlic, bitterweed, etc., and the loss occasioned by mechanically injurious weeds, such as the fruits of buffalo bur, *Solanum rostratum*, the awns of grasses such as squirrel tail grass, *Hordeum jubatum*, etc. The miscellaneous losses are estimated at $500,000 per year.

ESTIMATED TOTAL WEED LOSS IN INDIANA (1920).

Estimated tillage loss	$11,105,450
Estimated loss due to reduced yields	27,415,000
Estimated discount losses	3,394,920
Estimated loss due to land rendered incapable of profitable cultivation	100,000
Estimated cost of clearing weeds from railroad rights of way	150,000
Estimated damage by turf weeds	200,000
Estimated cost of cutting roadside weeds	157,000
Estimated cost of cutting pasture weeds, waste-place weeds, etc.	1,050,000
Estimated miscellaneous loss	500,000
Grand total	$44,072,870

or approximately $14 per capita per year.

What Are We Going to Do About It?

The grand total of forty million dollars' loss caused by weeds in a single year in Indiana, is probably very conservative. Cut the esti-

mate into half, and the loss is still enormous. Although it is readily conceded that the estimates are far from accurate, nevertheless the startling figures obtained are thought to be as nearly correct as it is reasonably possible to estimate. The staggering loss attributed to weeds should cause us to pause and think more seriously of the weed problem than has been our custom.

The question naturally arises, what are we going to do about it? The following suggestions are offered as possible aids in the solution of this vast problem:

1. The use of clean, pure, viable seed is fundamental in the control of weeds. Unless pure seed is used, all other efforts to cleanse our fields will be of little avail. Good seed will solve the problem to a large extent. In this connection, the recent seed law, which will be actively enforced on and after January 1, 1922, is of great importance, since it will enable the farmer to know the viability and purity of all agricultural seed purchased from dealers. The law provides that agricultural seed offered for sale in Indiana shall be labeled, the label to state: (a) the name of the kind and variety of seed, (b) the minimum number of seeds per pound of certain weeds designated as noxious that are present in seed offered for sale, (e) the place of origin of the seed and (f) the name and address of the vendor.

2. The importance of killing weeds before they mature seeds can hardly be over-emphasized. The destruction of seedling weeds is not difficult, but when weeds are allowed to mature seeds the difficulties are multiplied manifold. Weed seeds may remain viable in the soil for a number of years, a constant menace to future crops. The mowing of pastures before the weeds mature seeds will gradually drive the weeds out and permit the pasture plants to come in. The thorough preparation of the seed bed is also very important, since thousands of weed seedlings are destroyed by this means. Again, it pays to cut a weedy hay crop early, before the weeds have had a chance to mature seeds.

3. The results of recent experiments indicate strongly that after the preparation of the seed bed, the principal, if not the only, object of cultivation is the destruction of weeds. The more general use of the sweep or knife type of cultivating implements in soils adapted to their use will aid in solving the weed problem in tilled crops. This is particularly true in corn that is planted in check rows.

4. Roadsides, fence rows and waste places generally are centers from which surrounding farm land is constantly being infested with weeds. The roadside and fence-row weeds should be mowed on June 15th and again on August 15th. The more general use of the spud and hoe against waste-place weeds is much to be desired.

5. The threshing machine is a common and efficient carrier of weeds from farm to farm. The thresher should be thoroughly cleaned after each operation.

6. Sheep are excellent weed eradicators. It is highly profitable to turn weeds into mutton and wool. A few sheep on every farm in Indiana will help materially in solving the weed problem.

7. Give the land a chance to grow profitable crops. Maintain fertility by the use of lime and the addition of organic matter and

fertilizers and drain where necessary. A luxuriant growth of pasture or turf grasses, for instance, will crowd out the weeds.

8. Many grain-field weeds can be controlled by the use of a weeder or a spike-tooth harrow in the young grain, a practice that is usually more profitable than the use of sprays and other spectacular devices.

9. Clean cultivation, crop rotation, and the use of smother crops will eradicate or control the incidental weeds. A few weeds, such as the wild garlic, Canada thistle and dodder must be dealt with by special methods.

10. Co-operation among farmers is an important factor in weed control, inasmuch as weeds are a community as well as an individual problem. Many weeds, for instance, are disseminated by wind-distributed seeds. It avails a man little to eradicate the Canada thistle on his farm if the seeds from a neighbor's land are allowed to reinfest the clean fields. Roadside weeds in particular present a problem that can be solved by concerted action only. A realization of the seriousness of the situation should arouse sentiment in favor of co-operative action.

Purdue University.

PELORIA IN LINARIA AND OTHER PLANTS.

LOUIS F. HEIMLICH.

Peloria is a term derived from the Greek meaning monstrous. Applied to flowers, it is a kind of monstrosity or malformation. It is usually defined as "the phenomenon when usually irregular flowers, such as those with some of the petals or sepals spurred or saccate, develop all the parts of each set alike, thus becoming radially symmetrical." This condition was first observed and described by Linnaeus, "who found the spurred flowers of the Butter and Eggs or Toad flax (Linaria vulgaris) with five spurred petals instead of the normal one." To this condition he gave the name peloria.

Linaria is a genus belonging to the Figwort family (Scrophulariaceae). Peloric flowers of various species of this family have been reported from time to time in different countries. The species having such flowers are Linaria vulgaris Hill (4, 5, 6, 7, 8, 9, 10, 12),* Linaria dalmatica and other species of Linaria (6, 12), the snapdragon (Antirrhinum majus L.) (6, 12), and the foxglove (Digitalis purpurea L.) (4, 6, 12). Many other instances of peloric flowers of other families

Fig. 1. Linaria vulgaris Hill. Toad flax or Butter and Eggs. Normal plants to the left bearing normal flowers with one spur. Abnormal plants to the right bearing peloric flowers with five spurs.—Photograph by Mr. E. J. Kohl.

* The numbers in parenthesis refer to the same numbers opposite the references at the end of this paper.

"Linaria vulgaris Hill"
...Floral and Fruit Features of Normal and Peloric Plants...

Fig. 2.
A typical
Peloric
flower.

A
typical
Normal
flower.
Fig. 3.

Fig. 4.
Corolla
lobes of
a normal
flower.

Fig. 5.
Corolla lobes
of
a peloric flower
which have
remained 2-lipped.

Fig. 6.
Normal flower
with lower lip
displaced showing
the didynamous
stamens.

Fig. 7.
Basal portion of
a peloric flower
showing five stamens
in two sets, two stamens
being longer than the other three.

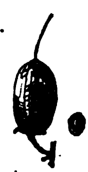

Fig 8.
Capsule and seed
of
a normal plant.

Fig. 9.
Capsule and seed
of a peloric plant—
the former much smaller
than the capsule of a normal plant.

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Some additional Abnormalities of Floral parts.

Fig. 10.
PICEA EXCELSA L.
An abnormal cone developed from a terminal bud bearing microsporophylls with large sporangia and a middle zone of sterile scales shaped like megasporophylls.
- Heterogamy.

Fig. 11.
CALENDULA OFFICINALIS L.
Floral proliferation of the inflorescence.

Fig. 12.
DELPHINIUM BELLADONNA.
Phyllody of the calyx. A sepal in each case has reverted partially to the leaf condition in form and color.

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are on record, which indicates that pelorism as a mutation is frequent (6, 12). Fig. 1.

Prior to October, 1921, the author knew nothing of peloria, although he had seen and collected various kinds of monstrous flowers. At the time above noted the author's attention was directed by Dean Stanley Coulter to a peculiar modification of the flowers of Linaria found growing along a street in the city of Lafayette. These peculiar plants were discovered by Miss Hester Meigs, a student of Jefferson high school. The writer visited the place twice and collected both normal and abnormal plants. Whole plants of each kind were pressed and dried and flowering portions of each kind were preserved in formaldehyde. Seeds of the normal plants were very plentiful, but only a few seeds were obtained from the peloric plants. Transplants were also collected and these are now sending up new shoots. After having disposed of the material in satisfactory manner for safe-keeping, the subject was investigated.

The normal plants were identified as Linaria Linaria (L) Karst. of Britton and Brown (or Linaria vulgaris Hill of Gray) and here below the genus description it is stated that the corolla, especially the terminal one of the raceme, occasionally has five spurs and is regularly five-lobed, and is then said to be in the peloria state (7). In Gray's Manual it is noted that in abnormal specimens the corolla is sometimes regularly five-spurred (8). Several large dictionaries give short definitions for the term peloria, but most of the ordinary botany books and the Encyclopaedia Britannica do not contain the term and the condition is alluded to in only two (9, 10) of the general texts examined, one of which states that regular flowers become diversely irregular and irregular kinds perfectly regular (9). This book advises the examination of Masters' Vegetable Teratology. (An old English book, London, 1868, 534 interesting pages.)

The normal flowers of Linaria have an irregular corolla with one spur at the base. The corolla is two-lipped, the upper lip erect and two-lobed, covering the lower in the bud. The lower lip is three-lobed and spreading (Fig. 3). There are four stamens which are didynamous (in two pairs of unequal length) (Fig. 6). The seeds are numerous in numerous capsules (Figs. 1, 8).

From an examination of the plants with abnormal, that is, with peloric flowers, it was found that differences existed in different peloric flowers. The corolla in all flowers examined was regularly five-spurred, the spurs alternating with the calyx lobes. The corolla tube tapered gradually to the top, where it was rolled over and divided into five small lobes which were quite regular in most cases (Fig. 2). In some instances, however, the lobes were unequal, there being a tendency to develop into two lips, the upper lip being pronounced and of two lobes, the lower lip consisting of the usual small middle lobe and two much smaller lateral lobes (Fig. 5). In all cases these more or less slight variations of lobes were found on plants with many flowers, all being pelorized, having five spurs.

All of the peloric flowers examined had five stamens instead of the normal didynamous stamens (Fig. 7). In some of the flowers there

were three short stamens and two longer ones (Fig. 7), while in others all stamens were of practically the same length, i. e. regular. Balfour (Encyclopaedia Britannica IV, 1876) has stated that in some instances by pelorization it is found that tetradynamous plants become tetrandrous.

In the peloric plants collected only a very few seeds were produced. The capsules producing them were smaller than the normal capsules (Figs. 8, 9). In 1860 Darwin stated that "there is, I believe, only one case on record of a peloric flower being fertile" (1). DeVries in his experiments begun in 1886 hand pollinated peloric flowers of Linaria which produced considerable seed (6).

Before proceeding further the definition of peloria must be modified. It is a kind of abnormality (but not any kind) of the corolla. It may be slight or pronounced, complete or incomplete. It is usually understood to mean a change from irregularity to regularity—designated as a kind of reversion (as in Linaria), but it may also be just the reverse. In the latter case radial flowers become zygomorphic (4). Examples of this are seen in many Compositæ when corollas of the disk florets become strap-shaped, as in the cultivated asters, sunflowers, and chrysanthemums. In still another case the peloric condition arises from the failure of the development of regular normal parts. Normal columbine flowers have five spurs. Peloric columbine flowers with no spurs at all have been reported (4). It is also noted that the spur in Linaria species is sometimes obsolete (7). Peloria is connected with floral variation in general and it has been of specific interest in the problem of mutation (1, 6).

What is the cause of such floral malformation? The cause is not determined. Some believe that a change in relation to light is a prominent factor, especially one-sided illumination appearing favorable for the development of peloria (5). DeVries in his experiments on Linaria sought to observe the anomaly in his pedigree cultures. The experiments were begun in 1886 with normal plants. A few peloric flowers were produced, which is not uncommon in this genus. The next few generations produced nothing more than the normal number of peloric flowers. In the third generation, among many thousands of flowers, there occurred one having five spurs. This was inbred by hand and produced much seed. All other seed was discarded. The next generation contained about twenty plants having only one peloric flower among them. The peloric plant and one other were bred together, producing abundant seed. From this seed fifty plants were produced. Eleven of them bore the normal number of peloric flowers. One plant was found to bear peloric flowers only. This was, according to DeVries, a mutation, for it bred true in future generations (6).

It seems that many plants produce a few peloric flowers occasionally or more or less regularly, but that individuals which are wholly peloric are comparatively rare. In the observations of last October more than a dozen individuals were noted which were wholly peloric.

It is said that flowers far surpass all other organs in the abundance of abnormalities and monstrosities (9). Besides Linaria three other floral monstrosities have come to the author's notice. One of these is a case of phyllody of the calyx of Delphinium belladonna,

grown by Mr. E. J. Kohl. The monstrosity is a reversion. One sepal is prolonged and divided and is also partly green, i. e., leaf-like in two respects (Fig. 12). Another monstrosity is a variation in the head of Calendula grown in the writer's garden. Instead of the usual head, some flowers are changed into small heads set on long pedicels. This is a floral proliferation of the inflorescence (Fig. 11). A number of such abnormalities occurred on one plant. The third monstrosity is a peculiar modification of a spruce cone (Picea excelsa L.) in which a cone bearing microspores (pollen) developed from a terminal bud, the normal place for a normal megacone. No leaves were produced from the bud. The lower part of the cone consists of very small, loose scales with rather large microsporangia full of microspores. The middle zone is made up of sterile scales similar in form to megasporophylls. This is evidently a case of heterogamy. (Fig. 10.) (Collected by author on Purdue campus.)

Peloric forms have been of little significance in horticulture (4). Peloria and other abnormalities, however, are of biological interest in discovering certain natural laws. All kinds of organic abnormalities are worth investigation, as is clearly shown by many of our cultivated plants which, like the navel orange, Fultz wheat and other kinds of wheat, the copper beech, the Shirley poppy, and cupid sweet pea, all of which arose from sudden variations or mutations.

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PLANTS OF WHITE COUNTY—IV.

LOUIS F. HEIMLICH.

Heretofore the author has reported two hundred species of plants as growing wild in White County. The list below includes seventy additional species. Specimens of these species were collected in the vicinity of Reynolds and at several places along the Tippecanoe river north of Monticello. The collection dates were September 4, 5, and 6, and October 30, 1921. The nomenclature, for the most part, is that of Gray's 7th edition New Manual of Botany. The authenticity of this list is vouched for by Mr. Charles C. Deam, of Bluffton, Indiana, who determined or verified every specimen. The numbers following the names refer to the specimen numbers in the author's personal collection. Brief notes are attached to a few species which seem to be of more than passing interest.

Pteridium latiusculum (Desv.) Maxon. Bracken fern. This is the Pteris aquilina L. of present manuals. Nos. 558, 583.

Polystichum acrostichoides (Michx.) Schott. Christmas-fern. No. 559.

Thelypteris palustris Schott. (*Aspidium thelypteris* (L) Sw.) Marsh shield fern. No. 629.

Osmunda regalis L. Royal fern. No. 630.

Sagittaria latifolia Willd. Broad-leaved arrowhead. No. 570.

Alisma subcordatum Raf. American water-plantain. Nos. 237, 571.

Sorghastrum nutans (L) Nash. Indian grass. No. 576.

Panicum dichotomiflorum Michx. Spreading Witchgrass. No. 620.

Echinochloa Crus-galli (L) Beauv. Barnyard-grass. No. 619.

Cyperus speciosus Vahl. Michaux's cyperus. No. 598.

Cyperus strigosus L. Straw-colored cyperus. No. 567.

Betula nigra L. Red or river birch. No. 647. In 1916 the author reported Betula lutea Michx. Yellow birch, Nos. 436, 437, as growing along the Tippecanoe about two miles south of Buffalo. (Proc. Ind. Acad. of Sci. 1917, pages 396 and 443.) It is now believed that these specimens should be referred to B. nigra L.

Urtica gracilis Ait. Tall wild nettle. No. 603.

Polygonum tenue Michx. Slender knotweed. No. 582.

Polygonum Muhlenbergii S. Wats. Swamp persicaria. No. 639.

Polygonum pennsylvanicum L. Pennsylvania persicaria. No. 600.

Polygonum Hydropiper L. Water smartweed. No. 599.

Polygonum Convolvulus L. Corn bindweed. No. 623.

Amaranthus hybridus L. Spleen amaranth. No. 612.

Berberis vulgaris L. European barberry. No. 645. The specimen is from Buffalo, collected October 30, 1921. The stems and leaves indicate that the specimens are probably the variety purpurea. The leaves were unaffected by rust.

Hydrangea arborescens L. Wild hydrangea. No. 560. This specimen was taken on the west bank of the Tippecanoe River just south

of the mouth of the Hoagland ditch. Mr. C. C. Deam has a record of this species from Miami County, about three miles east of Peru. These two records represent the northern limit of the species in Indiana as known at present. It is suspected that the species may be found farther north along the Tippecanoe.

Agrimonia parviflora Ait. Many-flowered agrimony. No. 587.

Medicago lupulina L. Black-seed hop-clover. No. 638.

Amorpha canescens Pursh. Lead plant. No. 608.

Desmodium canadense DC. Canadian tick-trefoil. No. 572.

Lespedeza virginica (L.) Britton. Slender bush clover. No. 563.

Lespedeza capitata Michx. Round-headed bush clover. Nos. 564, 648. Specimens referred to this species vary considerably.

Acalypha virginica L. Narrow-leaf form. Virginia three-seeded mercury. No. 595.

Chamaesyce Preslii (Guss.) Arthur. (Euphorbia Preslii Guss.) Upright spotted spurge. No. 604.

Chamaesyce maculata (L.) Small. (Euphorbia maculata L.) Spotted spurge. No. 596.

Ceanothus americanus L. New Jersey tea. No. 557.

Hypericum prolificum L. Shrubby St. John's wort. No. 646.

Hypericum mutilum L. Dwarf, small-flowered St. John's wort. No. 594.

Hypericum gentianoides (L.) BSP. Orange weed, Pine grass. No. 609. Found only in very sterile sandy soil.

Helianthemum canadense (L.?) Michx. Frostweed. No. 584.

Lechea Leggettii Britt. & Holl. Leggett's Pin-Weed. No. 628. Reported thus far only from Allen, Newton and Starke Counties. Description in Gray is erroneous.

Apocynum cannabium L. Indian hemp. No. 618.

Asclepias incarnata L. Swamp milkweed. No. 605.

Ipomea pandurata (L.) Meyer. Wild sweet potato. No. 634.

Verbena urticaefolia L. Nettle-leaved vervain. No. 614.

Verbena bracteosa Michx. Large-bracted vervain. No. 613.

Verbena hastata L. Blue vervain or Wild Hyssop. Nos. 597, 602.

Solanum nigrum L. Black, deadly, or garden nightshade. No. 616.

Aureolaria pedicularis var. ambigens (Fernald) Farwell. Fern-leaved or Lousewort false foxglove variety. This is the Gerardia pedicularia var. ambigens Fernald of Gray. No. 556.

Aureolaria flava (L.) Farwell. Smooth false foxglove. No. 644. This is the Gerardia virginica (L.) BSP. of Gray.

Agalinis purpurea (L.) Britton. Large purple agalinis. No. 574. (Gerardia purpurea L.)

Agalinis tenuifolia (Vahl.) Raf. Slender agalinis. No. 574A.

Pedicularis lanceolata Michx. Swamp lousewort. No. 554.

Galium pilosum Ait. Hairy bedstraw. No. 643.

Lobelia syphilitica L. Great lobelia or Blue cardinal flower. No. 552.

Vernonia fasciculata Michx. Western ironweed. No. 632.

Liatris scariosa Willd. Large button snakeroot. No. 553.

Solidago nemoralis Ait. Field or dwarf golden-rod. No. 580.

Euthamia remota Greene. Slender fragrant golden-rod. No. 586. The nearest description of this species in Gray is Solidago tenuifolia Pursh.

Aster furcatus Burgess. Forking aster. No. 561. Reported thus far from only Warren and Tippecanoe Counties. According to Deam it is rare. Specimen No. 561 taken from west bank of Tippecanoe River just south of mouth of Hoagland ditch.

Aster azureus Lidl. Sky-blue aster. No. 601.

Aster umbellatus Mill. Tall flat-top white aster. No. 592.

Aster linariifolius L. Stiff or Savory-leaved aster. Nos. 555, 581. This species is now reported by Deam from Harrison, Jasper, Lake, Porter, Starke, and White Counties. It is very fond of sandy soil.

Erigeron canadensis L. Horseweed, Canada Flea-bane. No. 610.

Gnaphalium polycephalum Michx. Sweet life-everlasting. No. 627.

Silphium terebinthinaceum Jacq. Prairie dock. No. 633.

Helianthus mollis Lam. Hairy sunflower. No. 590.

Helianthus grosseseratus Martens. Saw-tooth sunflower. No. 589.

Coreopsis palmata Nutt. Stiff tickseed. No. 579.

Coreopsis tripteris L. Tall tickseed. No. 591.

Bidens frondosa L. Beggar's ticks. No. 622.

Cirsium discolor (Muhl.) Spreng. Field thistle. No. 562.

Prenanthes racemosa Michx. Glaucous white lettuce. No. 573.

Hieracium scabrum Michx. Rough hawkweed. No. 631.

Hieracium Gronovii L. Gronovius' or Hairy hawkweed. No. 585.

Purdue University.

THE GROWTH OF TREE TWIGS.

C. A. LUDWIG.

METHODS AND RESULTS.

During the summer of 1921 the writer made a series of measurements[1] of growing tree twigs. This was with the idea of throwing what light might be possible on the nature of the plants and on the nature of growth, but more specifically of attempting to determine definitely if in the absence of irrigation reliable data can be secured in humid regions for determining the normal course of the growth rate.

There were available two thrifty young peach trees, *Prunus Persica* (L.) Stokes, and some plants of flowering dogwood, *Cornus florida* L. The first peach tree was on a slight northern slope and was rather tardy in starting growth. The other was on a southern slope but was shaded considerably by tall forest trees some distance away. It started growth sooner than the other, and as the results to be presented show, stopped growing sooner. Neither bore any peaches, as the fruit was killed by a late spring freeze. Three of the flowering dogwoods were along the south edge of a patch of woodland where they were unshaded throughout the summer. A fourth was within the forest and was shaded as soon as the forest trees had developed their leaves. The dogwood is well known as a shade enduring tree, and there was no indication that the small shaded tree used in this study was diseased or weakened by reason of the shading. None of the dogwood trees were large enough to bloom this season. The measurements were made from the base of the shoot to the base of the terminal bud and were taken to the nearest one-eighth inch. They were subject to a maximum experimental error of about $\pm$ 0.125 inch, aside from the "probable" error (error of sampling), on the individual measurements. The experimental error of the averages is considerably less, but even the greater error would produce only a negligible alteration of the growth curve.

The shoots measured on the two peach trees were divided into two classes: (1) shoots which were not so situated as to be over-topped and shaded by others; and (2) shoots which were so situated as to be shaded. The means for the shoots of class one of the first tree and the corresponding growth increments are given in Table 1. The same data are shown graphically in Fig. 1. The weekly rainfall summations are also shown at the top of the figure. I am indebted for the rainfall records to the local co-operative Weather Bureau station. The number of twigs measured was eleven for all dates except March 29th, when it was seven, the seven shoots then measured being included in the population of eleven used on all succeeding dates. The data for class two of the first tree are given in Table 2, Fig. 2. The number of twigs was 19 for March 29th, and 22 for all succeeding dates.

[1] I am indebted to my wife, Mrs. Nelle McClurg Ludwig, for necessary aid in making and recording these measurements.

Table 1. Growth of unshaded shoots on peach tree No. 1.

Date	*Mean length*	*Mean increment*
March 29	1.49	....
April 5	2.44	0.95
April 12	4.22	1.78
April 19	5.19	0.97
April 26	7.71	2.52
May 3	11.06	3.35
May 10	15.14	4.08
May 17	19.97	4.83
May 24	25.53	5.56
May 31	32.15	6.62
June 7	38.03	5.88
June 14	43.26	5.23
June 21	48.38	5.12
June 28	52.16	3.78
July 5	55.05	2.89
July 12	56.91	1.86
July 19	58.47	1.56
July 26	59.61	1.14
August 2	60.33	0.72
August 9	60.98	0.65
August 16	61.32	0.34
August 23	61.51	0.19
August 30	61.58	0.07
September 6	61.57	—0.01
September 13	61.59	0.02

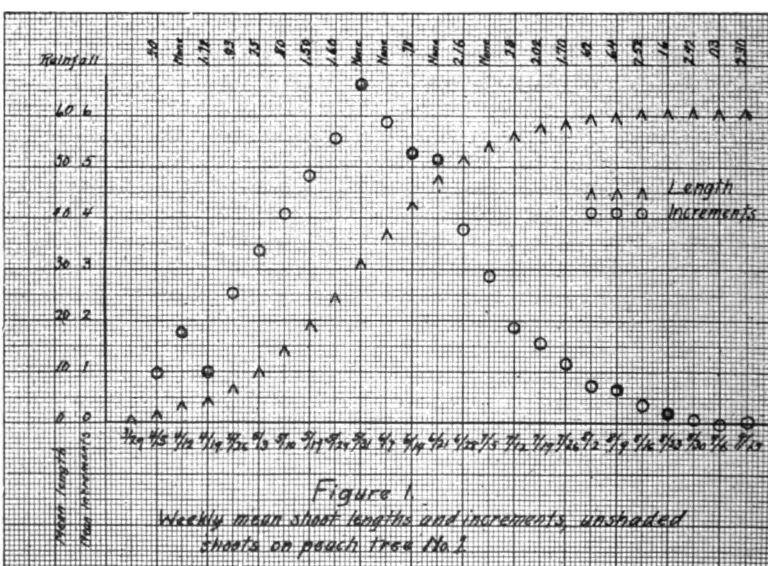

Figure 1. Weekly mean shoot lengths and increments, unshaded shoots on peach tree No. 1

Table 2. Growth of shaded shoots on peach tree No. 1.

Date	*Mean length*	*Mean increment*
March 29	1.23	....
April 5	2.11	0.88
April 12	3.58	1.47
April 19	4.59	1.01
April 26	6.59	2.00
May 3	9.23	2.64
May 10	12.34	3.11
May 17	15.53	3.19
May 24	18.89	3.36
May 31	22.85	3.96
June 7	25.89	3.04
June 14	28.34	2.45
June 21	30.15	1.81
June 28	31.41	1.26
July 5	32.23	0.82
July 12	32.72	0.49
July 19	32.95	0.23
July 26	33.11	0.16
August 2	33.13	0.02
August 9	33.14	0.01
August 16	33.08	—0.06
August 23	33.05	—0.03
August 30	33.09	0.04
September 6	33.07	—0.02
September 13	33.09	0.02

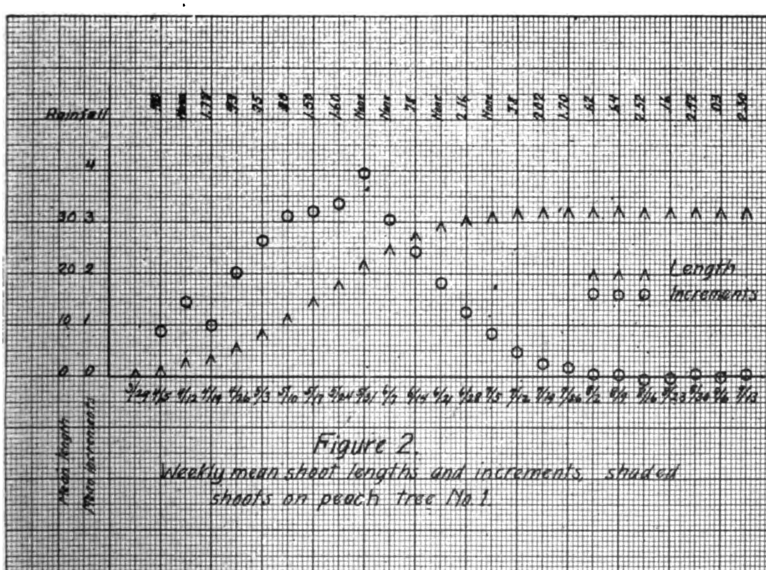

Figure 2.
Weekly mean shoot lengths and increments, shaded shoots on peach tree No 1.

The corresponding data for peach tree No. 2 are given in Tables 3 and 4 and Figs. 3 and 4. The numbers of shoots involved in these cases are 7, 18 and 9, 10, respectively.

Table 3. Growth of unshaded shoots on peach tree No. 2.

Date	*Mean length*	*Mean increment*
March 29	3.64	....
April 5	5.98	2.34
April 12	9.72	3.74
April 19	11.31	1.59
April 26	14.56	3.25
May 3	18.08	3.52
May 10	21.39	3.31
May 17	24.17	2.78
May 24	27.28	3.11
May 31	30.73	3.45
June 7	32.89	2.16
June 14	34.08	1.19
June 21	34.27	0.19
June 28	34.30	0.03
July 5	34.36	0.06
July 12	34.34	—0.02
July 19	34.34	0.00
July 26	34.44	0.10
August 2	34.42	—0.02
August 9	34.47	0.05
August 16	34.38	—0.09
August 23	34.36	—0.02

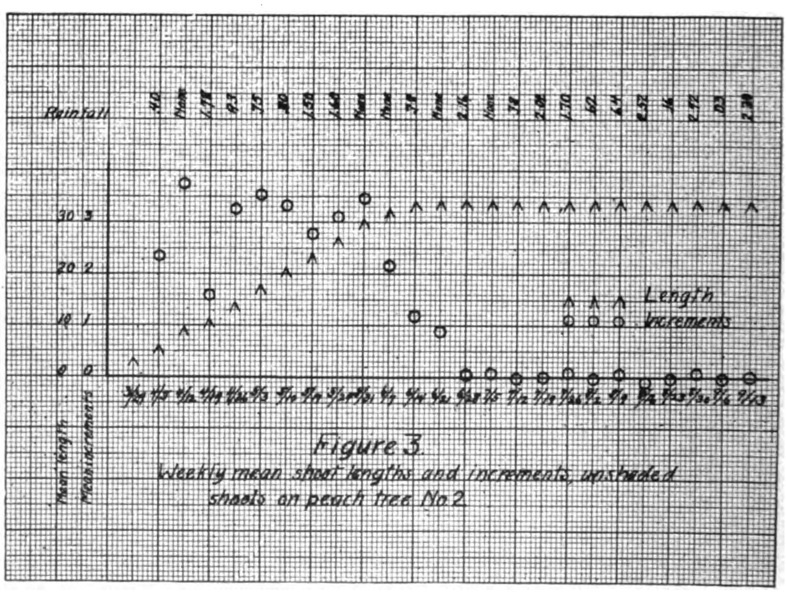

Figure 3.
Weekly mean shoot lengths and increments, unshaded shoots on peach tree No 2

Date	Mean length	Mean increment
August 30	34.44	0.08
September 6	34.42	—0.02
September 13	34.42	0.00

Table 4. Growth of shaded shoots of peach tree No. 2.

Date	Mean length	Mean increment
March 29	2.61	....
April 5	4.54	1.93
April 12	7.53	2.99
April 19	9.08	1.55
April 26	11.56	2.48
May 3	13.56	2.00
May 10	15.00	1.44
May 17	15.91	0.91
May 24	16.74	0.83
May 31	17.36	0.62
June 7	17.68	0.32
June 14	17.86	0.18
June 21	17.91	0.05
June 28	17.89	—0.02
July 5	17.96	0.07
July 12	17.94	—0.02
July 19	17.94	0.00
July 26	17.98	0.04
August 2	17.98	0.00
August 9	17.96	—0.02
August 16	17.94	—0.02

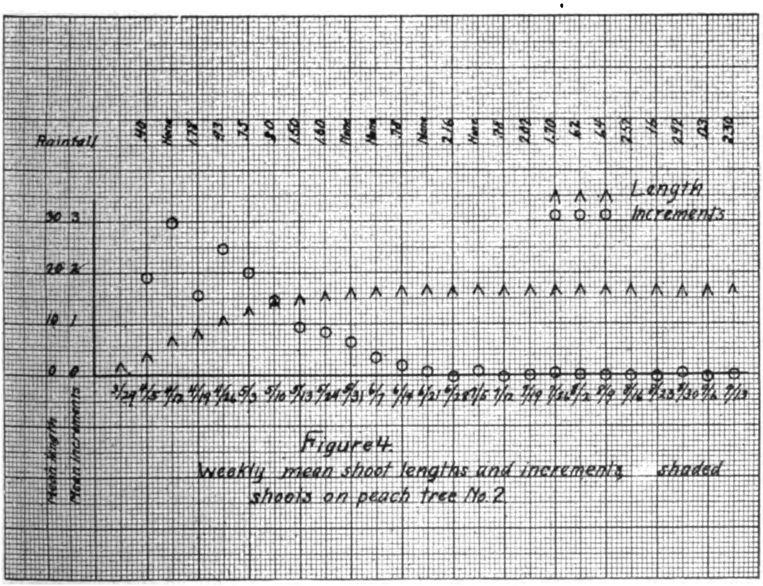

Figure 4.
Weekly mean shoot lengths and increments shaded shoots on peach tree No 2

Date	*Mean length*	*Mean increment*
August 23	17.91	—0.03
August 30	17.94	0.03
September 6	17.91	—0.03
September 13	17.91	0.00

The data for the dogwood shoots were divided into two groups. The first included those shoots from the trees on the edge of the forest and the second those on the shaded tree. The first had 41 members and the second group had 19. The mean lengths and growth increments for these two groups are given in Tables 5 and 6 and shown graphically in Figs. 5 and 6.

Table 5. Growth of unshaded shoots of dogwood.

Date	*Mean length*	*Mean increment*
March 29	0.42	....
April 5	0.72	0.30
April 12	1.17	0.45
April 19	1.43	0.26
April 26	1.79	0.36
May 3	2.33	0.54
May 10	2.69	0.36
May 17	3.42	0.73
May 24	4.18	0.76
May 31	5.00	0.82
June 7	5.40	0.40
June 14	5.75	0.35
June 21	5.82	0.07
June 28	5.86	0.04

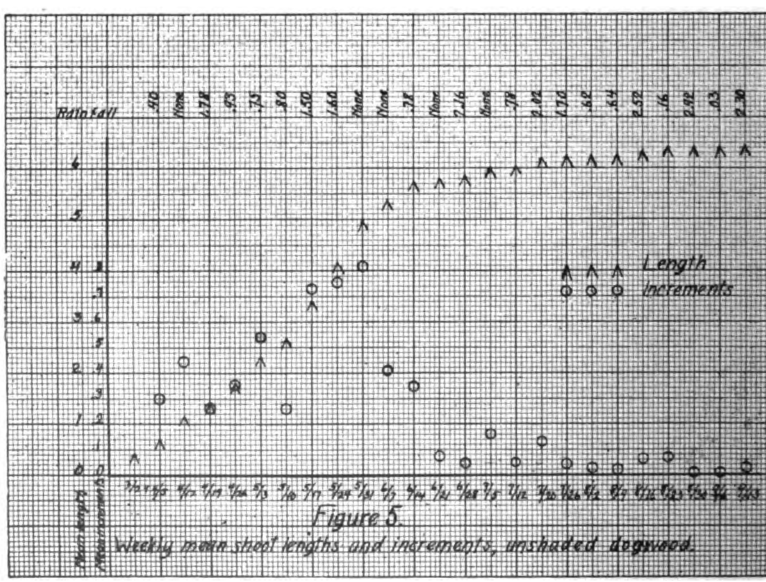

Figure 5.
Weekly mean shoot lengths and increments, unshaded dogwood.

Date	*Mean length*	*Meun increment*
July 5	6.02	0.16
July 12	6.07	0.05
July 20	6.21	0.14
July 26	6.25	0.04
August 2	6.28	0.03
August 9	6.30	0.02
August 16	6.36	0.06
August 23	6.43	0.07
August 30	6.44	0.01
September 6	6.45	0.01
September 13	6.48	0.03

Table 6. Growth of shoots of shaded dogwood bush.

Date	*Mean length*	*Mean increment*
March 29	0.42	....
April 5	0.68	0.26
April 12	1.00	0.32
April 19	1.20	0.20
April 27	1.41	0.21
May 3	1.45	0.04
May 10	1.53	0.08
May 17	1.56	0.03
May 24	1.61	0.05
May 31	1.68	0.07
June 7	1.70	0.02
June 14	1.74	0.04
June 21	1.73	—0.01

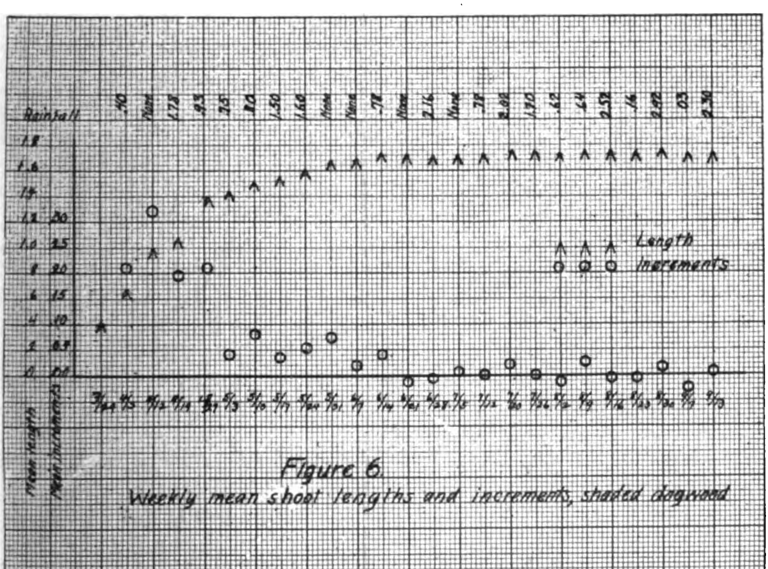

Figure 6.
Weekly mean shoot lengths and increments, shaded dogwood

Date	Mean length	Mean increment
June 28	1.72	—0.01
July 5	1.73	0.01
July 12	1.73	0.00
July 20	1.75	0.02
July 26	1.75	0.00
August 2	1.74	—0.01
August 9	1.76	0.02
August 16	1.76	0.00
August 23	1.75	—0.01
August 30	1.76	0.01
September 7	1.74	—0.02
September 13	1.74	0.00

The dogwood shoots which developed from terminal buds were further divided on the basis of whether they were true terminal branches or were lateral branches of the pseudo-whorl which develops from the terminal bud in the spring. The mean final lengths of these branches were determined for each group and for the two groups combined. The results are shown in Table 7.

Table 7. Final mean length of the true terminal branches and of lateral branches from terminal buds in dogwood.

Group	Type of shoot	Number of shoots measured	Mean length
1	True terminal	12	4.40
1	Lateral	21	7.44
2	True terminal	6	.54
2	Lateral	13	2.30
All	True terminal	18	3.11
All	Lateral	34	5.47

Discussion.

Since the data secured come from a limited number of trees and shoots under different and varying environmental conditions it will not be possible to reach conclusions concerning the normal seasonal course of the growth of tree twigs under uniform outside conditions. Furthermore, it is probably not possible to obtain such curves in humid regions without recourse to irrigation unless an exceptionally good year should happen to be found, or if the observations should be extended over a sufficiently large number of seasons to equalize variations in rainfall. Even then one season's observations under irrigated conditions ought to be more reliable. The present season's rainfall was fairly uniform, and yet the growth curve seems to have been affected rather definitely by rainfall variations. However, the variations in the conditions give certain advantages in interpretation which would not be secured were the conditions uniform.

The curves all show the same general type. The growth rate at first is slow, it increases to a maximum, and then decreases to zero as the season advances. The initial slowness of growth is not very clearly indicated by the data for the shaded dogwood bush, nor for the shaded shoots on peach tree No. 2, but it would doubtless be more evident if

it had been practical to take one or two earlier sets of measurements. The type of curve is shown best of all in the unshaded shoots of peach tree No. 1.

It will be noted that peach tree No. 1 and group 1 of the dogwoods reached their maximum growth rate during the week ending on May 31st. These trees were under very similar conditions. However, peach tree No. 2 grew much more rapidly early in the season but ceased growing sooner. The shaded dogwood reached its maximum earlier than the other but because of an earlier decline in growth and not because of a more rapid early growth.

The behavior of these two peach trees seems to point toward the conclusion that the early spring rate of growth is influenced a great deal by the temperature. Tree No. 2 had a considerably warmer location than No. 1. It should also be remarked in this connection that there was freezing weather on one or two occasions after these measurements were begun. It may be possible that if optimum temperature conditions had prevailed early in the season the growth rate would quickly have approximated that found later, after making due correction for the number of working hours per day which the plant has at the two periods.

The cause of the onset and continuation of a decreased growth rate was clearly not lowered temperature, however, because growth had stopped while the temperature was still at a point at which rapid growth occurred earlier in the season. The evidence from the rainfall is that variation in the water supply was at least partially responsible. It seems reasonable to suppose that in the case of peach tree No. 1 and dogwood group No. 1 the growth rate would have continued to augment for some time longer but for the onset of drier weather. In the case of the shaded dogwood the decrease in growth was probably caused by shading. Although no record was made of the time when the forest trees had expanded their leaves sufficiently to produce full shade it was noted that growth in the shaded dogwood seemed to stop shortly after this occurred. It was also noted on the peach trees that as soon as a branch became shaded it quickly ceased growing. This was true whether the shoot came from a last season's bud or was a lateral on a shoot of this season's growth. This observation would account, at least partially, for the more rapid decrease in the growth rate of branches which became overtopped, as shown by the curves for the two peach trees.

In view of the work of Garner and Allard[2] on the effect of the relative length of day and night on the onset of the flowering stage of plants it is worthy of suggestion that this factor also may be operative in such cases as this. It is a common observation that hardy woody plants usually cease growing and harden their twigs while the weather is still warm enough for good growth, whereas in the spring they begin growing very shortly after the weather warms up sufficiently.

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[2] Garner, W. W., and H. A. Allard. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agr. Res. 17:553-606. 1920.

Owing to the lag of the seasonal curve of temperature the days of given length in spring are much cooler than days of the same length in the fall.

This study has suggested a few interesting points concerning the dogwood which do not have to do directly with the growth rate. The dogwood is well known as a shade enduring tree. The quickly declining growth rate of the shaded tree in this study suggests that this ability on the part of the dogwood is not due to an unusual power to grow in the weak light of the forest, but rather to an ability to grow for a few weeks in the spring and then spend the entire remainder of the season slowly storing up food for another few weeks' growth the next spring.

Another interesting fact, which is shown by Table 7, is that, contrary to the condition in most trees, the terminal shoot in the dogwood is shorter than the laterals of the same season's growth. Each terminal shoot, as it starts growth in the spring, produces one or more very short internodes and sends out one or two lateral branches from each of the closely spaced nodes. There are thus from one to about six laterals produced in an arrangement which simulates a whorl. The measurements mentioned above show that the average final length of these laterals exceeds the final length of the terminal. Additional observations (without measurements) show that in upright, unshaded, rapidly growing stems the terminal exceeds the laterals, but that in the case of stems growing at an angle the lowermost branch grows the longest and becomes the leader, while the rest of the branches decrease in size till the innermost (or uppermost) one is reached, and the terminal is still smaller. Thus every year a new branch becomes the leader and each successive true terminal finally assumes the role of a minor branch. The result each season is to produce a more or less eccentric umbel shaped group from each terminal bud which opened that spring.

Summary.

A number of woody shoots were measured during one season's growth period. The results showed an initial slow growth rate, which then increased to a maximum, and later decreased to zero before the temperature had dropped to the point at which growth started in the spring. The slow initial rate in this case is believed to have been due to the cool weather at the time. The onset of the decrease in growth rate is believed to be due to a decrease in available moisture for at least part of the trees, and it is therefore considered impossible to get dependable curves for the normal course of a season's growth in tree twigs without having recourse to irrigation. For one of the trees and for some shoots on others the onset of the decrease in growth rate is believed to be due to shading, and it is suggested that in all cases the variation in relative length of night and day may have influenced the course of the cycle. The ability of the dogwood to live and develop in shady situations seems not be due to an ability to grow in poor light but rather to an ability to endure shade most of the season and at the same time to store food slowly for use in a spurt of growth in the fol-

lowing spring before the forest develops full shade. In branches growing at an angle the terminal shoot of dogwood grows less than any of the closely spaced laterals which start growth at the same time. The lowermost (outermost) branch grows the most and becomes the future leader of the branch.

Clemson College.

Observations Concerning Puccinia Pattersoniana and Puccinia Moreniana.[1]

E. B. Mains.

Puccinia Pattersoniana was described by Dr. J. C. Arthur[2] from material collected by F. W. Anderson at Sandcoulee, Cascade County, Montana, in July, 1888. The host was a grass, *Agropyron spicatum* (Pursh.) Rydb., and this rust has since been found on *Elymus condensatus* Presl., *E. triticoides* Buckl., and *Sitanion jubatum* J. G. Smith in Oregon, Washington, Utah, California, and New Mexico. *Puccinia Pattersoniana* is unique among the grass rusts in that it has verrucose teliospores with the markings arranged in longitudinal lines. While studying some collections of this rust, another interesting character was found in this species. It was noticed that chloral hydrate and iodine, which was being used to bring out the pore character of the urediniospores, stained the pedicels of the teliospores a dark blue. A study of other collections in the Arthur Herbarium, including the type, showed that this character held true for all. The pedicels stained very heavily, many becoming a very dark blue, appearing almost black for a greater part of their length. Herbarium specimens of this rust when sectioned and treated with iodine, showed the stain only in the pedicels of the teliospores, the mycelium from which they arose and the pedicels of the urediniospores not staining. This reaction of iodine appears similar to that found in some of the Ascomycetes (Plicaria, etc.), where the apical portion of the ascus takes a similar stain.

Further interesting light was thrown on this fungus in the summer of 1920 by Prof. A. O. Garrett,[3] who noted that apparently the only aecia associated with *Puccinia Pattersoniana* at Gogorza, Summit County, Utah, were on *Brodiaea Douglasii*, supposedly belonging to the autoecious *Uromyces Brodiaeae* Ellis & Hark. Prof. Garrett suggests that these aecia might be in reality the aecial stage of *Puccinia Pattersoniana*, since the latter was especially abundant there, and he was not able to find any further development of the rust on Brodiaea. Unfortunately attempts to prove this connection were unsuccessful, since the teliospores from collections sent by Prof. Garrett failed to germinate the next spring. It occurred to the writer, however, that some definite evidence might be obtained as to this connection by the method so successfully used by Tranzschel[6] in connecting several heteroecious rusts with their aecial stage. In making these connections, he made use of the observations made by Dietel[4] and Fischer,[5] who noted that a num-

[1] Contribution from the Botanical Department, Purdue University Agricultural Experiment Station.

[2] Arthur, J. C. Bull. Torrey Club 33, p. 29, 1906.

[3] Garrett, A. O. Mycologia 13, p. 104 and 110, 1921.

[4] Dietel, P. Uredinales. In Engler & Prantl. Natürliche Pflanzenfamilien I. 1** p. 69. 1897.

[5] Fischer, Ed. Beiträge Kryptogamen Flora Schweiz 1, p. 109, 1898.

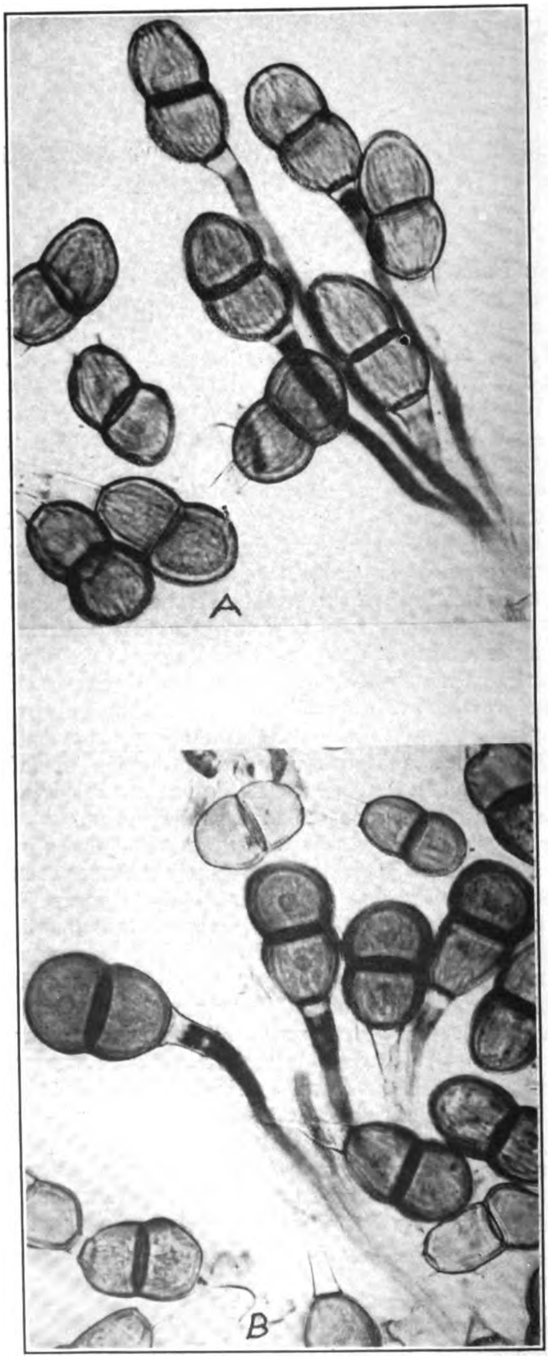

PLATE I.

ber of short cycled species of rusts possessed teliospores very similar to the teliospores of heteroecious long cycled species whose aecia were produced on the host of the short cycled species. Thus Tranzschel[6] noted the striking similarity between the teliospores of *Puccinia Pruni-spinosae* Pers. on *Amygdalus communis* and the teliospores of *Puccinia fusca* Winter on Anemone. *Aecidium punctatum* Pers., an unconnected aecial form, was known to occur upon Anemone and when aeciospores from this were sown on *Amygdalus communis, Puccinia Pruni-spinosae* was produced. In like manner several other rusts were successfully connected.

In consequence, it was thought that if *Puccinia Pattersoniana* is connected with aecia on Brodiaea, a short cycled rust having teliospores with the distinguishing characteristics of those of *P. Pattersoniana* should occur on some species of Brodiaea. In order that this search might be as complete as possible, all the species represented in the Arthur herbarium, which occur on Brodiaea, were examined, including *Puccinia Carnegiana* Arth., *P. subangulata* Holw., *P. Dichelostemmae* D. & H., *P. tumamocensis* Arth., *P. nodosa* Ell. & Hark., *P. Moreniana* Diet. & Thomp. and *Uromyces Brodiaeae* Ellis & Hark. Of these only *Puccinia Moreniana* on *Brodiaea capitata* Benth. showed teliospores with pedicels staining with iodine and these took a dark blue stain similar to those of *Puccinia Pattersoniana.* Not only does *P. Moreniana* resemble *P. Pattersoniana* in this respect but the teliospores of the two are nearly identical in size, wall thickness and in the verrucose markings in lines

In the light of the observations of Dietel and Fischer and the work of Tranzschel, the striking resemblance between the teliospores of these two rusts strongly indicates that *Puccinia Pattersoniana* has its aecial stage on Brodiaea. This also, when taken with the field association noted by Prof. Garrett, can leave but little doubt as to the connection.

[6] Tranzchel, W. Travaux de la Soc. Imper. des Naturalistes de St. Petersbourg **25**:286-297. 1904. Abstract in Botanishes Centralblatt **98**:150-151. 1905.

DESCRIPTION OF PLATE

PLATE 1

A.—Teliospores of *Puccinia Pattersoniana* from the type collection on *Agropyron spicatum* with pedicels stained blue by iodine.

B.—Teliospores of *Puccinia Moreniana* from the type collection on *Brodiaea capitata* with pedicels stained blue by iodine.

Evidence of the Seed Carriage of the Euphorbia Rusts, Uromyces Proeminens and U. Dictosperma.[1]

E. B. Mains.

As part of the investigations of the life cycles of rusts being carried on by this laboratory, two species of Uromyces, *U. proëminens* (DC.) Pass. and *U. dictosperma* Ellis & Ev., have been studied. *U. proëminens* (*U. Euphorbiae* Cooke & Pk.) was studied by Carleton,[2] who showed that this rust was carried by the seed of *Euphorbia dentata* Michx. Arthur[3] showed that this species was autoecious by sowing the aeciospores from aecia on *Euphorbia Preslii* Guss. ("*E. nutans*"), obtaining uredinia and telia on the same host. The writer's attention was attracted to this rust on account of the more or less systemic aecia which persist throughout the season, the heavy production of aecia, uredinia and telia on the fruit, and the evident strains which exist in this rust in the vicinity of Lafayette, Ind. *U. dictosperma* is a species found on *Euphorbia Arkansana* Eng. & Gr. and other species farther west in Nebraska, Kansas, Texas and westward. The life history of this species has been in question, first as to whether the systemic aecia on these hosts belong to this species or to some heteroecious species, and second as to whether uredinia are produced in the life cycle.

Uromyces proëminens.

In the fall of 1920, seed was collected from plants of *Euphorbia dentata* which were heavily rusted with telia of this rust. In the field this species does not appear until midsummer, so that by starting the plants in the greenhouse there is no chance for infection from without. The seed was planted the 22d of January and about the time the first leaves were well developed, sixty of the plants were transplanted to a flat. Infection first showed up March 1st, when pycnia appeared upon one capsule of one plant. Following this, other plants showed pycnia or aecia or both. Since there was some variation in the manner of development on the various infected plants, each will be discussed separately.

Plant 3-4.

The rust showed on this plant as pycnia upon one of the terminal capsules of the main shoot March 1st. March 27th, two more capsules showed pycnia and both pycnia and aecia appeared on the leaves of the secondary branches arising from the axils of the cotyledons. May 4th, aecia also had appeared on the terminal fruits. No further de-

[1] Contribution from the Botanical Department Purdue University Agricultural Experiment Station.

[2] Carleton, M. A. U. S. Dept. Agri. Bureau Plant Ind. Bull. 63 p. 9-11. 1904.

[3] Arthur, J. C. Bot. Gaz. 29 p. 271. 1900.

velopment of the rust on this plant was noted, the new branches being rust free.

Plant 3-2.

This plant showed pycnia April 7th on the secondary branches arising from the axils of the cotyledons. Upon April 19th, pycnia and aecia showed on the secondary branches. Following this throughout the summer up until September 3d, the plant continued to send out new branches most of which were covered with pycnia and aecia. No other stages developed.

Plant 5-4.

This plant first showed rust on April 19th, when pycnia appeared covering the capsules and leaves of the two secondary branches. On April 27th, pycnia also appeared upon one capsule of the central shoot and aecia appeared intermixed with the pycnia on the secondary branches. Part of the new branches, as they developed during the summer, showed pycnia and aecia covering the leaves and capsules.

Plant 6-5.

On April 19th, pycnia and aecia appeared on the leaves and capsules of the secondary branches, and on May 4th, pycnia showed on the terminal capsules of the main shoot. On May 5th, uredinia appeared scattered over the plant. Shortly afterward, the plant died.

Plant 9-4.

On April 19th, pycnia and aecia appeared on the capsules and the leaves of the secondary branches. On April 27th, two of the capsules of the main shoot showed pycnia, followed by aecia May 4th. On May 4th, aecia apparently without pycnia appeared upon the leaves of two new branches. On May 11th, uredinia appeared scattered over the plant. About June 3d, the plant died without showing any further development of the rust.

Plant 4-4.

On April 19th, aecia apparently unaccompanied by pycnia appeared on the capsules of the secondary branches. No further development of the rust occurred.

Plant 4-3.

On May 11th, this plant showed pycnia on the capsules of the main shoot. On July 3d, several new branches also had pycnia. No further development of the rust occurred.

In all, seven of the sixty plants showed infection either with pycnia or aecia or with both. As indicated above, there was some variation as to the manner in which infection showed and developed. In some cases it appeared first on the terminal capsules of the main shoot, following later on the secondary branches. In some cases the plant outgrew the infection and became rust-free with the dying of the infected branches.

In other cases the infection developed with the plant throughout the season, invading the new branches as they were formed. In general pycnia appeared first, followed shortly by aecia. Occasionally pycnia only appeared and in a few instances apparently only aecia developed.

Aeciospores from the above material were sown on five uninfected plants and uredinia and telia of *U. proëminens* were produced upon the leaves and capsules. Later ten other plants became infected, showing uredinia and telia apparently from the aeciospores and urediniospores of infected plants.

Uromyces dictosperma.

Seed from plants of *Euphorbia Arkansana* heavily infested with telia of *U. dictosperma* was collected by Mr. E. Bartholomew at Stockton, Kansas, July 2, 1920, and sent to Dr. J. C. Arthur, who kindly turned the material over to me for this work. This seed was planted August 20, 1920, forty-two plants being obtained. These were transplanted to a flat September 2d, and upon November 12th one plant showed infection, one branch being covered with aecia. This infected branch soon died and all the plants appeared free from rust until the last of March, when a number showed infection. The plant showing aecia in November again showed aecia upon one of its branches. Out of the forty-two plants, eleven showed infection, aecia or pycnia and aecia developing upon one or two branches. Later uredinia and telia appeared on most of the plants apparently from aeciospore infection. The branches infected with aecia soon died without setting seed and the plants finally showed only telia.

Aeciospores from the above described material were sown on uninfected plants and uredinia were produced. The urediniospores in these sori were, however, soon replaced by the characteristic teliospores of *Uromyces dictosperma*. From these cultures it is evident, therefore, that the more or less systemic aecia found on *Euphorbia Arkansana* associated with the teliospores of *U. dictosperma* represent the aecial stage of this rust. Aeciospores from these aecia give rise to uredinia, which, however, as such, exist for only a short time, the urediniospores being replaced by teliospores. *Uromyces dictosperma* in consequence is a full-cycled, autoecious species.

It is considered that the above evidence is sufficient to prove that these two rusts are seed carried. The press of other work has not allowed the question to be investigated as to how this takes place. The investigations of Carleton would indicate that in the case of *Uromyces proëminens* the rust was carried on the surface of the seed since plants from seed treated with corrosive sublimate showed no infection. To explain the production of aecia, it would be necessary to assume, however, that teliospores were carried on the seed and germinated while the plant was still young. In the above experiments the teliospores would have to germinate in the fall without overwintering, while in the field they would germinate in the spring after overwintering. Carleton was not able to obtain germination from the teliospores which were present on the seed at the time of planting. In consequence the manner in which this rust is seed carried will have to be left for future investigations.

TREATMENT OF RHUS POISONING.

O. P. TERRY.

It seems there are almost as many "cures" for rhus poisoning as there are people susceptible to it. These cures vary from an ounce dose of epsom salt (taken internally, of course) to applications of Tr. Iodine and solutions of sugar of lead externally.

Those who know themselves to be susceptible to the poison should investigate the possibility of immunizing themselves by taking Tr. rhus toxicodendron. This paper outlines a successful method of treating the dermatitis after it has appeared. No claim of originality is made in the selection of the drugs used, but, it is believed, something new will be found in the manner of their application.

The following paragraphs give in order the steps in the treatment and if begun within a few hours after exposure to the poison will prevent the inflammation.

(1) Thoroughly wash the exposed skin with a heavy lather of laundry (strongly alkaline) soap in warm water, using a soft brush.

(2) Immediately mop off the skin with cotton saturated with ethyl alcohol (denatured with phenol is preferable).

(3) Then apply Tr. grindelia, using a pledget of cotton or soft cloth. Continue the application of this at four-hour intervals until all itching has ceased or until practically all swelling has disappeared. The skin now will feel dry and drawn. (The length of time required for this part of the treatment will vary from two to five days, depending upon the susceptibility of the patient to the poison and also upon the length of time elapsing between exposure and the beginning of the treatment. An average is about three days.)

(4) For the purpose of restoring the surface of the skin to a normal condition, now may be applied a mixture of 1/3 ounce each of ethyl alcohol, glycerine, and rose water, to which is added ten grains of phenol. This softens and aids in the exfoliation of the dead epidermis.

Purdue University.

INDIANA FUNGI—VI.

J. M. VAN HOOK.

The first paper of this series on the subject of Indiana Fungi,* which was undertaken in 1910, was a mere list of those fungi which appeared to be, for the most part, new to our State. In the five papers previously published, we have recorded 724 species. In the later papers we have gradually added more data concerning each species, in many cases now entirely rewriting descriptions. Where only fragments of descriptions are given, it is to be understood that such fragments are additions to, or differences from, the original.

Investigators, particularly in the field of the so-called Imperfect group, are amazed at the many meager descriptions by which one is expected to identify his specimen. If the host were unknown, it might easily be placed under any one of a dozen species. *Spots* are often described as "epiphyllous" or "hypophyllous" when it is very evident that the writer had in mind "pycnidia," "acervuli" or "conidiophores." It is very evident that spots on living leaves are practically always *amphigenous*, but differing sometimes only in color. The characteristics of spots both on the upper and lower sides of leaves should be described.

Much new, rare or extraordinary interesting material has been made available by Mr. H. M. Hudelson, who is collecting particularly the fleshy and woody forms.

Where the name of the collector is omitted, it is understood to be that of the writer; when the locality of its occurrence is not given, it is to be presumed that it was collected in Monroe County.

ASCOMYCETES.

Hysteriographium gloniopsis (Ger.) E. & E.

On decorticated *Ulmus americana*, Monroe County, 1907. Indiana University number 3809. The spores of this fungus remain hyaline for a long time.

Podosphaera biuncinata Cke. & Pk.

On leaves of *Hamamelis Virginiana*, Stephens Creek, October 17, 1920. 3846.

BASIDIOMYCETES.

USTILAGINALES.

Entyloma compositarum Farl.

On living leaves of *Ambrosia trifida*, Stone Springs, June 30, 1920. 3830.

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* Indiana Fungi-I, 1910, 459 species.
Indiana Fungi-II, 1911, 71 species.
Indiana Fungi-III, 1912, 27 species.
Indiana Fungi-IV, 1915, 99 species.
Indiana Fungi-V, 1920, 68 species.

Entyloma serotinum Schroet.

On living leaves of *Mertensia Virginica*, Harrodsburg, May 7, 1921. 3865. At this early date, this fungus had already killed the lower leaves of its host. The similarity of leaf spotting by certain species of Entyloma to those caused by Imperfect Fungi is strikingly noticeable here.

UREDINALES.

Gymnosporangium germinale (Schw.) Kern.

On branches of *Juniperus Virginiana*, Weimar Lake, April 24, 1921. 3863. Collected also at Harrodsburg. Found on twigs and branches of all sizes up to an inch or more. Our specimens agree well with the description given by Arthur except that spores are usually constricted and many much longer than given. The average length is fully the extreme recorded by him. We find spores more than 80 microns long.

HYMENOMYCETALES.

Clavariaceae.

Clavaria inequalis Fr.

In large palm pot, greenhouse, May 17, 1921. Also in September. Plants white, upper half somewhat yellow. Some enlarged slightly on top; others rounded.

HYDNACEAE.

Hydnunt caput-ursi Fr.

On decayed log (*Nyssa sylvatica*), Bean Blossom Valley, November 12, 1921. Hudelson. 3909.

POLYPORACEAE.

Boletus chrysenteron Fr.

Ground, open woods, July 6, 1921. 3877.

Polyporus fragrans Pk.

On bark of log (*Ulmus americana*), Bean Blossom, November 12, 1921. Hudelson. Has odor of sweet anise and licorice. 3908.

Poria undata (Pers.) Bres.

City Water Works, October 27, 1908. 2192. (See Mycologia, *12*, 89, 1921.)

Trametes sepium Berk.

On stake of deciduous wood, Campus of I. U., October 14, 1921. 3384. Common on structural timber.

AGARICACEAE.

Clitopilus prunulus Fr.

On ground, Griffey Creek, June 23, 1921. Hudelson. 3873.

Cortinarius distans Pk.

On ground, Bean Blossom, June 27, 1921. Hudelson. 3874.

Lepiota cristata Fr.

Ground, I. U. Campus, July 6, 1921. Paul E. Harris. 3876.

Pleurotus spathulatus (Fr.) Pk.

On ground, Bean Blossom, September 27, 1921. Hudelson. 3882. This species is very similar to P. petaloides but has spores 7½ by 4 to 5 microns, whereas the latter has globose spores, 3 to 4 microns.

Russula foetentula Pk.
Griffey Creek, June 20, 1921. Hudelson. 3782. Distinguished by the cinnabar red color at the base of stem.

PHALLINALES.

Mutinus elegans (Mont.) E. Fisher.
On ground in woods, Monroe County, June 10, 1921. 3885.

LYCOPERDINALES.

Bovistella Ohiensis Ell. & Morg.
On ground, Bean Blossom, June 15, 1921. Hudelson. 3870.

PLECTOBASIDINALES.

Scleroderma Geaster Fr.
On a clay bank, Bean Blossom Valley, September 27, 1921. Hudelson. This is an interesting fungus, seeming to prefer a rather raw clay situation. They are easily overlooked, as only the top is visible, this being split sometimes into star-like segments but often in a very irregular manner. They ordinarily split one-fourth to one-third of the distance from the top. They are from two to four inches in diameter. 3596 and 2883. (Bovistella Ohiensis Morg. number 3596 in Indiana Fungi IV, for 1915, should be referred here.)

FUNGI IMPERFECTI.

SPHAEROPSIDALES.

Phyllosticta circumvallata Wint.
On somewhat languishing leaves of *Liriodendron tulipifera.* Also on circular spots due to the common catalpa midge. July 22, 1921. 3879. Harris.

Phyllosticta Podophylli Wint.
On living leaves of *Podophyllum peltatum,* Cedar Cliff, May 6, 1921. 3867. Huckleberry ravine, May 24, 1921. Anderson. 3868. This fungus is common in Monroe County and varies from the description as follows: Pycnidia, almost wholly epiphyllous, 100 to 150 microns in diameter with a definite pore about 20 microns in diameter. Spores irregularly globose or ovoid, granular, 9 to 12½ by 7 to 10 microns. The arrangement of the pycnidia along the veins is very noticeable.

Septoria verbascicola B. & C.
Common in Monroe County, on *Verbascum blattaria.* I. U. Campus, August 7, 1908. 2386.
Spots, 1 to 6 mm. in diameter, white center with broad purplish border, circular, amphigenous; pycnidia mostly epiphyllous, prominent, rupturing the epidermis, dark, pore small, wall thin and easily rupturing about the pore; spores hyaline, long bacilla-like, curved, flexuous or straight, as much as 50 microns long and .5 to 1 micron thick. (The ease with which the pycnidia rupture above may cause it to be placed under the Melanconiales in hasty study.) Since no description of this plant is given in Saccardo,

it is herein described as shown in our local fungi. Professor C. H. Kauffman, of the University of Michigan, has kindly compared specimen number 749 of the exsicatti of Ellis' N. A. F. with the above description and says that it agrees well with it.

MELANCONIALES.

Cylindrosporium Capsellae E. & E.

On living leaves of *Lepidium Virginicum*, six miles west of Bloomington, July 25, 1920. 3861.

The measurements of the spores on this new host agree well with those in the description, except that they are only 12 to 30 by 2 to 2½ microns, while in Ellis and Everhart's original description they are given as 35 to 45 by 3. We have two specimens collected on Capsella Bursa-pastoris. The spores in these are slightly longer, measuring 15 to 37 by 2 to 2½. They are variously curved and are 1 or 3-septate, not uniform in thickness and occasionally pointed at one end. Though differing somewhat from the original description, it seems proper to refer this specimen to C. Capsellae E. & E. In addition to the spore difference noted above, the acervuli are hypophyllous as well as epiphyllous.

Marsonia Thomasiana Sacc.

On living leaves of *Evonymus atropurpureus*, Showers' Farm, August 26, 1920. 3811.

Spots 1 to 6 mm. broad, usually 1 to 3 mm., amphigenous, subcircular or angular, with reddish margin; acervuli amphigenous, erumpent through the cuticle, 25 to 50 microns and later often extending so as to cover most of the spot and leaving a white, flaky appearance due to the adbundance of spores drying in masses; spores 17 to 30 by 8 to 12 microns, mostly about 20 to 25 by 10, pyriform, usually constricted at the septum; the upper cell twice the width of the lower one, subspherical and occasionally not exactly above it but tilted slightly to one side by the lower cell being bent; conidiophore very short cylindric, about 4 to 7 by 4 to 5 microns.

HYPHOMYCETES.

Cercospora avicularis Wint.

Common on living leaves of *Polygonum* species throughout Monroe County. 2805. Collected on the Showers' Farm, August 20, 1920. Spots scattered, amphigenous, 1 to 6 mm., brown in dried specimens, bounded by a narrow elevated reddish-brown line, yellowish outside this line; tufts of conidiophores chiefly epiphyllous; conidiophores short, about 25 by 4 microns, colored at the base; conidia pale yellow (almost hyaline), 3 to 7-septate, curved or straight, 40 to 90 by 3 to 4 microns. Distinguished from C. polygonacea E. & E. by its short conidiophores.

Cercospora depazeoides (Desm.) Sacc.

On living leaves of *Sambucus Canadensis*, Showers' Farm, August, 1920. 3810. Our specimen agrees with the European type rather than with C. sambucina E. & K. collected in New York and Kansas. The spots agree with those described for C. depazeoides except

that they are 2 to 6 mm. This covers both the sizes described for C. depazeoides and for C. sambucina (4 to 6 and 2 to 4 respectively). The conidiophores agree also with the European form except that we have a minimum length of 50 microns. While the spores are for the most part 75 by 5 microns, they range from 50 to 115 by 5 to 5½. It seems rather remarkable that our Indiana specimens should agree so well with the European form as compared with those from New York and Kansas situated as we are between the two States. In our judgment C. sambucina E. & K. is not sufficiently different from C. depazeoides to constitute a separate species. The "shot hole" effect of the fungus upon the leaves is very noticeable in our specimens.

Cercospora granuliformis Ell. & Mart.

On *Viola cucullata* (V. sororia), Kerr Creek, June 22, 1920. 3821. Varies from the description as follows: conidiophores 3 to 4 microns in thickness; conidia 20 to 62 long, straight or sometimes bent, cylindrical or enlarged near the base, 1 to 5-septate (mostly about 3), hyaline and not brown. Our specimens have many things in common with C. Violae Sacc., C. murina Ell. & Kell. and C. granuliformis Ell. & Holw. These common characters suggest a too close relationship of these species.

Cercospora Nasturtii Pass.

On leaves of *Radicula Nasturtium-aquaticum* at a spring one mile southeast of Bloomington, July 24, 1921. 3880. Large areas of this cress were killed by this fungus at this date. It appeared as follows: spots circular, 1 to 10 mm. (eventually spreading over and killing the entire leaf), pallid, with ochraceous border; conidiophores amphigenous, fuscous, light colored at the tips; conidia 40 to 112 by 4 to 6 microns, 3 to 7-septate (many are 4-septate), cylindrical to long tapering, some cells thicker than others, hyaline. Our specimens bear great resemblance to several species and varieties of Cercospora described on various Cruciferae, some of which seem too closely related.

Cercospora murina Ell. & Kell.

On *Viola cucullata*, I. U. Campus, July 13, 1916. 3700.

Cercospora Rubi Sacc.

On leaves of blackberry, Weimar Lake, October 21, 1920. 3851. Further study of specimen number 3655 reported in 1915 (Indiana Fungi IV) as C. septorioides E. & E. seems to assign it here. As stated there, C Rubi Sacc., C. rubicola Thuem. and C. septorioides E. & E. have many common characteristics, while our specimens differ somewhat from all of them as follows: spots amphigenous, one-third to one cm., orbicular, at times somewhat limited by veins, wood-brown to avellaneous, becoming paler with age, bounded by a purplish-fuscous border; conidiophores densely aggregated, short, 15 to 30 by 3 to 4 microns, wavy above; spores 30 to 100 by 2 to 4 microns, continuous to 7-septate, most of the larger ones slightly curved and 5 or 6-septate.

Isariopsis laxa (Ell.) Sacc.

On leaves and pods of beans (*Phaseolus vulgaris*), Clark County, Indiana, August, 1920. 3816.

So far as the writer is able to learn, this is the first time this fungus has been recorded as injuring or growing upon bean bods. During the month of August, 1920, and to some extent during the same month of 1921, a number of gardens were completely ruined by this disease. It appeared first upon the leaves, then attacking the pods, spotting and rotting them. The appearance of the spots upon the pods is entirely unlike that caused by anthracnose. They are usually larger, more superficial at the beginning, and present a blotched appearance around the edge. Further work is being done to determine more definitely the exact nature of and the conditions necessary to cause bean pods to be severely injured by this fungus. This fungus was first noted in America by Ellis under the name of *Graphium laxum Ell.* Bull. Torr. Club, 1881, p. 65.

Ramularia Plantaginis Pk.

On living leaves of *Plantago Rugelii*, six miles west of Bloomington, July 25, 1920. 3833 and 3858.

Our specimens have spots 1 mm. to 2 cm. in diameter, brown, with small light colored center. Specimen number 3633 has much smaller spots than 3858. Conidiophores amphigenous, and especially abundant near the outer edges of the spots, wavy in outline, and bearing spores laterally as well as terminally, about 25 microns long. Spores cylindrical, rounded at the upper end, somewhat truncate below, 12 to 45 by 4 to 5 microns, continuous, becoming 1 or even 2 or 3-septate. This fungus corresponds well with the too brief description by Peck in Report 32, 1879. Ramularia Plantaginis Ell. & Mart. is said to have minute spots. The descriptions of these two species, however, seem, in the light of our material, to be near if not identical. From the fact that conidiophores are found in the outer brown part of the spots, it seems better to describe spots as brown with pale center rather than, spots small, pale with broad border. Since Peck's description antedates that of Ell. & Mart., it seems preferable to refer our specimens to R. Plantaginis Pk.

Sterigmatocystis nigra V. Tiegh.

On bread, July 14, 1921. 3878.

MYXOMYCETES.

Tubifera ferruginosa (Batsch.) Gmelin.

On pieces of rotten wood, I. U. Campus, June 26, 1921. O'Neal. 3875. Tops of sporangia even more pointed than figured by MacBride, and the figure shows them more pointed than warranted by the descriptions.

Indiana University.

The Popping of Corn.

Paul Weatherwax.

The ability of the grains of some varieties of Indian corn to "pop" when heated lends a unique interest to this otherwise unusually interesting plant, and a number of popular notions and more or less scientific theories have attempted complete or partial explanations of the phenomenon.

Kraemer's detailed histological studies lead him to the belief that the popping of corn is due to peculiarities in the minute structure of the starch grain.

Wilbert showed, in 1903, that the "pop" was due to the expansion of moisture in the grain, and that corn too dry to pop well could be improved by soaking in water and then partially drying. He also found that the hull of the grain plays no essential part, and that the pop starts in the densest pheripheral portion of the grain.

Attacking some old ideas as to the popping process, Storer found, in 1904, that the expansive medium responsible for popping was not a volatile oil. He also found that the hull of the grain was not necessary, since pieces of grains would pop the same as whole grains.

A year ago at the meeting of this Academy, Carr and Ripley revived the problem by inquiring into "What puts pop in popcorn?" Disposing of the history of the question with the statement that it is often "joked about but seems never to have been considered seriously enough to lead to any investigation", they discuss certain observations and experiments on a number of varieties of popcorn. They state that the expansive medium causing the pop is steam generated within the starch grain, and that between a wide range of extremes the moisture content is immaterial. In explaining how the pressure is confined for a time and then suddenly released, they state (p. 264): "The cellular starch wall is very elastic, permitting of wide distention, and a loss of some cell granules, without breaking. Other corn grains split open without much cell elasticity being shown." Although this terminology cannot readily be translated into standard terms as applied to cell structure, it is taken to mean that the cell wall is the structure responsible for the peculiarity, and that popcorns differ from other varieties with respect to this structure. They emphasize the important point that successful popping requires the dextrinization of most of the starch, and this requires that the heat be applied at an optimum rate.

In the light of significant results coming from recent investigations, this seems an appropriate time to collect and evaluate the data afforded from all sources and to generalize on the subject.

Nature of the Process.—The popping process is in reality a miniature explosion caused by the slow application of heat, and resulting in a disruption in which the endosperm increases greatly in volume, often

turning the grain inside out. Physical examination shows a profound change in the texture of the endosperm, the cell walls being destroyed, the starch grains exploded, and other characteristics of organic structure obliterated; and chemical analysis indicates hydrolysis of most of the starch and a considerable loss of moisture.

Two factors here present themselves for explanation: (1) the expansive medium acted upon by the heat; and (2) the structure which gives force to the explosion by confining the accumulating pressure until a limit is reached.

Most of the investigators of the subject up to the present have been physicists and chemists, and they have satisfactorily solved the problem involved in the first of these factors, the expansive medium. But they have failed to locate the confining structure, because here the clue is afforded by the difference between popcorn and kinds of corn that do not pop; and this falls within the field of plant morphology.

The Expansive Medium.—An old idea, that the expansive medium, acting as a vehicle for the disruptive force, was a small volume of air imprisoned in the middle of the grain, seems long ago to have been abandoned for want of evidence. And the more recent one, attributing the explosion to a volatile oil, has gone by the same route. The significant changes that occur in popping indicate that the disruptive force is distributed throughout the endosperm, while analysis shows that the oil content is limited to the embryo of the grain.

The occurrence of maximum and minimum moisture contents for good popping—although the range is wide—and the visible escape of steam during popping, indicate that water contained in the very hygroscopic starch grains themselves is the substance that expands and causes the explosion. At least a partial hydrolysis of the starch is necessary for best results, and this necessitates slow enough application of the heat to permit dextrinization before the explosion occurs. Experience has shown that best results are obtained when the popping temperature, which is 175° to 200° C., is reached in two to three minutes from the initial application of heat.

The Confining Structure.—The confinement of the increasing pressure until the instant of explosion was long attributed to the pericarp of the grain, but experiments do not bear out this idea. Pieces of grains will pop, as will also grains with holes drilled in them, and grains with the pericarp removed.

A microscopic examination of the endosperm of maize shows the contents of each cell to consist of numerous starch grains embedded in a mass of desiccated colloidal material, the protoplasm of the cell. This colloidal material is the seat of all the protein of the endosperm except that in the aleurone layer. The flinty or soft texture of the endosperm depends upon how completely the colloidal material fills the interstices between the starch grains. The moisture in the starch grain is changed to steam during the heating process, but the starch is held intact by the colloidal matrix until the limit of its capacity is reached. Then the explosion of the starch grains of a few cells at the surface, where the tissue is flintiest, releases the external pressure on underlying units, and the whole ten million grains let go simultaneously. The

cell wall is a comparatively fragile structure, incapable of holding any great pressure, and playing no significant part in the process. In the softer varieties of corn the steam generated during the application of the heat tends to leak out through the more porous matrix of colloidal material so that the explosion, when it finally occurs, is much less violent; and it comes at a lower pressure than in good popping varieties because the confining structure is not strong enough to hold a greater pressure.

All kinds of corn pop more or less, and the process is also characteristic of the seeds of many other species of grasses. But it is only in the small-seeded flint varieties known as popcorns, and in some of the sorghums, that the grain undergoes so great a change as is generally indicated in the popular term *popping*. The necessary structure for successful popping is a flinty endosperm. The range of moisture permissible is much wider than is generally supposed.

Popping and Protein Content.—Since the hardness of the endosperm is determined by the degree to which the interstices between the starch grains are filled with the colloid rich in protein, a close correlation might be expected between the popping quality and the protein content of the grain. A general correlation does occur, but analyses such as those given by Carr and Ripley (p. 262) show that it is not so close as might be expected.

It may be remarked in passing that the ordinary analysis of the whole grain of corn is scarcely more than useless in the solution of a problem like the one here at hand. A grain of corn consists of three separate and distinct parts—pericarp, endosperm, and embryo—members of three different morphological generations of the plant, and possessed of three distinct genetic possibilities, and capable of having three uncorrelated chemical compositions.

The protein concerned in the popping process is located in the interstices between the starch grains of the endosperm, that in other parts of the grain playing only a passive part. An analysis of the whole grain will indicate feeding qualities and many other things, but to take such an analysis as an index to popping qualities, or, as some have done, to the hereditary constitution of the embryo, is exactly as scientific as carrying out a nitrogen determination after spilling an unknown quantity of a substance of unknown composition into the digestion flask.

Analyses of endosperms carefully separated from the rest of the grains show a much closer correlation between protein content and popping qualities. But even here too much must not be expected. Protein content is only a matter of relativity after all. Starch grains vary much in size and in shape, and there is consequent variation in the amount of protein-bearing colloid necessary to fill all the spaces sufficiently to produce flinty translucency. The endosperm of the flintiest type the author has ever analyzed had only a little more than 6% protein, while that of a relatively soft, floury variety had more than 12%. Although the former had large enough a grain to be classified among the flints, it popped well; the latter merely split open when heated. But microscopic examination showed the one to have large,

hexagonal, closely-arranged starch grains, only a small amount of colloid being necessary to fill the interstices completely; the latter had small, rounded, loosely-arranged starch grains, and the relatively large amount of protein-bearing material was not sufficient to fill the spaces and produce a flinty texture. The difference between the two conditions is not wholly one of heredity, the weather conditions attendant upon maturity, and doubtless the chemical constitution of the soil, being determining factors.

Structure of the Starch Grain.—Kraemer's theory that the ability to pop is dependent upon the minute structure of the starch grain, is not readily substantiated. The extremes that he notes between popping and non-popping varieties in this respect can all be found in good popping varieties if enough samples are examined.

The "Puffed" Cereals.—Contrary to the opinion expressed by Carr and Ripley (p. 261), there is good evidence that in the manufacture of the "puffed" cereals exactly the same principle is involved as in the popping of corn, man having provided what nature omitted. The grain, containing a proper amount of moisture, is enclosed in an air-tight metal drum and heated until the optimum temperature and pressure have been reached. Then, by suddenly opening the drum, the pressure outside each grain of the cereal is released, and each starch grain explodes because of the internal pressure of the steam.

SUMMARY.

The popping of a grain of corn is an explosion due to the expansion, under pressure, of moisture contained in the starch grains. Until the instant of the explosion, this force is confined by the colloidal matrix in which the starch grains are embedded. Neither air nor any volatile oil is in any way concerned with the process as the expansive medium.

As a result of popping, there is hydrolysis of much of the starch, a loss of moisture, and the obliteration of all cellular structure in the endosperm.

Except to aid slightly in confining the pressure, neither the embryo nor the hull (pericarp) of the grain plays any part in the process.

Maximum, minimum, and optimum moisture contents are indicated, but the range is wide.

The flinty texture of the endosperm is an accurate index to popping qualities. Hardness of the endosperm is due to nitrogenous material filling the interstices between the starch grains; but, because of variation in the size, shape, and proximity of the starch grains,—and consequent variation in the relative amount of material necessary to fill the interstices,—popping quality is not in direct proportion to protein content.

The difference between popping and non-popping varieties is wholly one of hardness of endosperm. Popping is not in any way dependent upon the minute structure of the starch grain. Non-popping varieties may be made to pop if they are heated to the proper temperature under pressure and the pressure suddenly released.

For successful popping, the heat must be applied rapidly enough to generate steam faster than it escapes, but slowly enough to permit hydrolysis of most of the starch before the explosion occurs. Best results are obtained when the heat is so applied that a temperature of 175° to 200° C. is reached in 2.5 to 3 minutes.

Indiana University.

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Additions and Corrections to the List of Indiana Mosses.

T. G. Yuncker.

In the list of mosses of Indiana submitted to the Academy last year there were omitted, it has been discovered, several mosses that are reported as occurring in the State. These additional species were included in a list of mosses of Monroe County made by Professor F. L. Pickett and published in *The Bryologist* for May, 1915. There were, also, in this list several species not reported by me as occurring in Monroe County. In order that the list of last year may be made as complete as possible, I list below the species that were not previously included.

Species not included as occurring in Indiana.

Brachythecium rivulare B. & S.
Dicranella heteromalla var. *orthocarpa* (Hedw.) E. G. B.
Forsstroemia trichomitria var. *immersa* (Sulliv.) Lindb.
Hypnum molluscum Hedw.
Orthotrichum Lescurii Aust.
Orthotrichum Schimperi Hamm.
Rhytidium rugosum (L.) Kindb.

Species not reported as occurring in Monroe County:

Aphanorhegma serratum Sulliv.
Brachythecium campestre B. & S.
Bryhnia graminicolor (Brid.) Grout.
Bryum caespiticium L.
Buxbaumia aphylla L.
Campylium hispidulum (Brid.) Mitt.
Ceratadon purpureus (L.) Brid.
Cratoneuron filicinum (L.) Roth.
Dicranum fulvum Hook.
Eurynchium hians (Hedw.) J. & S.
Hedwigia albicans (Web.) Lindb.
Leptobryum pyriforme (L.) Wils.
Leucodon brachypus Brid.
Mniobryum albicans (Wahlenb.) Limpr.
Mnium affine Bland.
Philonotis fontana (L.) Brid.
Thuidium microphyllum (Sw.) Best.
Tortella caespitosa (Schwaeger.) Limpr.

The following errors in synonymy have also been observed in my previous list:

Polytrichum formosum Hedw. as reported is probably *P. ohioense* R. & C.
Bryum Wahlenbergii Schwaegr. is *Mniobryum albicans* (Wahlenb.) Limpr.
Thuidium tamariscinum B. & S. is probably *T. delicatulum* (L.) Mitt.

Anomodon fragilis is *A. tristis* (Cesat.) Sulliv.

Hypnum serpens radicle (?) is possibly *Amblystegium serpens* (L.) B. & S.

Hypnum riparium cariosum (?) is possibly *Amblystegium riparium* B. & S.

DePauw University.

A Chemical Study of the High Frequency Corona Discharge.

F. O. Anderegg.

All commercial methods of making ozone take advantage of the chemical properties of a corona or silent discharge. In order to prevent the undesirable spark discharge from forming it is necessary to use some device such as a dielectric. Glass, micanite or similar insulating material interposed between two electrodes is a great aid in the formation of a discharge suitable for ozone production. Dielectrics have several disadvantages; they cannot be used at high temperatures; they are apt to be easily broken mechanically and finally they are subject to annoyingly frequent punctures. Moreover, a dielectric undergoes progressive changes which are apt to have considerable effect on the yield of ozone.

The high frequency discharge has certain advantages which have made desirable some investigations of its availability for ozone production. Because of the time necessary to build up a spark discharge from small electrodes it is possible in a suitably designed tube to have brilliant corona discharges without the use of dielectrics.

In 1896 Nikola Tesla,[1] observing the production of ozone in air subjected to the discharge from certain forms of his high-tension high-frequency coils, applied for a patent. The electrodes were parallel plates; these do not produce a form of discharge very suitable for ozone production, so that this apparatus has not achieved any commercial success. The use of a high-frequency corona discharge in reducing the molecular weight of hydrocarbons so as to render them suitable for use as gasolene has been described by Cherry.[2] By this means, he has eliminated the dielectric, which, at the temperatures used (up to 480°), would give considerable trouble. Other investigators[3] working with frequencies as high as 1,200 cycles apparently have found optimum frequencies for certain conditions.

[1] N. Tesla. U. S. Patent 568, 177 Sept. 22, 1896.

[2] L. B. Cherry *Trans. Am. Electrochem. Soc.* **32**, 345 (1917). U. S. Patent 1229, 886 July 12, 1917. Doubtless a certain amount of cracking occurs under the given conditions. Indeed the use of a corona discharge primarily for cracking has been more recently patented. Schmidt and Wolcott. U. S. Patent. 1307, 931, June 21, 1919. The use of high frequency for polymerization of acetylene has been described by Kaufman, *Ann.* 417, 34 (1918).

[3] Shenstone and Priest, *J. Chem. Soc.* **63**, 938 (1898) concluded that the maximum efficiency is to be obtained with a 16 cycle discharge. Further discussion of the effect of frequency has been given by Rideal, Ozone, Van Nostrand, 1920, pp. 105-107, but it must be remembered that uncertainties as to meter readings and as to the effect of other uncontrolled variables render the conclusions drawn there of doubtful value. A comparison of a number of ammeters placed in the primary circuit of an induction coil operated on direct current showed that none of them registered the same value or even the true value as obtained from oscillographs. The maximum deviation was about 25 per cent. However, the tendency to use 500 cycles whenever available for commercial production of ozone must have some significance.

Experimental: Preliminary experiments were made with a small Tesla coil. One side of both the secondary and primary was grounded, the other end of the terminal ending in a platinum wire supported on the inside of a bell, similar to the method proposed by H. Guilleminot,[4] so that the corona discharge, which is produced under suitable electrical conditions, may ozonize the air. The Tesla coil was supplied with energy from a small induction coil. The concentrations of ozone were very small and the power yield was only 2-5 g. per killowatt hour on a basis of gross input into the induction coil. A more suitable arrangement for securing a corona discharge is a wire passing through the axis of a tube,[5] as previously used for the study of the direct current corona. At first a No. 29 platinum wire was placed in a five-inch aluminum tube. The results obtained were quite variable and it was thought that the variability of the direct current which excited the induction coil was responsible; but on applying storage battery current, the improvement was not great. An oscillographic study of the secondary current and of the voltage from a tertiary coil wound on the induction coil showed a very inconsistent wave form. Various make-and-breaks were tried without success. A 5,000 v. Thordarson type H-1 transformer was substituted and with a fairly constant source of alternating current gave results which were very much more consistent.

Description of Electrical Set-up. A very steady source of alternating current at 110 v. was applied through variable resistance to a Thordarson transformer of type H-1 whose ratio was 1:50. A condenser made of three concentric aluminum tubes, having a capacity of 0.0007 microfared, was placed in parallel with the high voltage terminals. A zinc spark gap with variable adjustment was used in an atmosphere of ether vapor. The Tesla coil was composed of four turns of wire in the primary and 200 in the secondary with an air core. The frequency was measured with a Kolster decremeter calibrated by the Bureau of Standards. The wave length varied according to the size of the wire in the tube and according to whether the measuring apparatus was connected to the tube or to the wire. With No. 29 wire, the wave length was 185 m. for the tube and 2000 m. for the wire, while with No. 16 wire, these values had increased to 260 and 300 m. respectively. The frequency, then, was in the range between 1 and 1.6 million cycles per second. Variations in the width of the spark gap and in the power-input had no effect on the wave length. Attempts to change the frequency by changing the capacity of the primary or secondary circuit of the Tesla coil or by changing the inductance of the secondary had no effect on the frequency but resulted in reducing seriously the secondary current as well as the corona discharge. Evidently an optimum set of dimensions of the circuit can be obtained for each tube according to its capacity. No attempt was made to work out the relationships involved. The electrical circuits used in this work were such as to give optimum discharge in the tube used. In other

[4] H. Guilleminot, *Compt. rend.* **136**, 1653 (1903) describes an apparatus but gives no data as to its chemical possibilities.

[5] F. O. Anderegg, *J. Am. Chem. Soc.* **39**, 2581 (1917).

words, the circuit must be "tuned" according to the dimensions of each discharge tube used.

Air dried by passing through sulphuric acid wash bottles and over freshly cracked potassium hydroxide was passed into one end of the corona tube at constant pressure. The flow rate was measured with the usual type of flowmeter. The corona tube was 193 cm. long and had an internal diameter of 4.65 cm. The volume with side arms was 3,402 cc. The wire was passed through small holes in glass plates which were cemented to the aluminum tube by a special wax[7] which has shown itself to be very resistant to the action of ozone. Inlet and outlet tubes were made by screwing short lengths of aluminum tubing into holes in the side of the tube near the end, and inside of these, glass tubes were sealed tight with the special wax. The first part of the absorption apparatus was made entirely of glass and the absorbing liquid was standard alkali by means of which nitrogen pentoxide, formed in the discharge, could be absorbed. The amount of ozone absorbed by the small volume of solution used was found to be well within the experimental error. To absorb the ozone two Erlenmeyer flasks were used. The rubber stopper in the first Erlenmeyer flask was protected by a very thin coating of beeswax, which was unaffected by the ozone during experiments lasting more than a year.

The procedure was to pass a corona discharge through still air enclosed within the tube or through air which was flowing through the tube at a definite rate. The pressure in the tube was maintained constant at 750 mm. The temperature was that of the room, 22-30°. Changes in temperature of 10° were shown to produce only very slight variations in yields. Results are given for different wires under various conditions of flow rate of air and under varying electrical conditions. The amperes, volts and watts of the primary circuit of the Thorardson transformer were recorded as well as the voltage across the spark gap. The current in the secondary of the Tesla coil was measured with a hot wire ammeter and reached values as high as half an ampere at 6,000-8,000 v. when the gross input into the system was less than 150 watts. A very poor power factor in this part of the circuit is thus indicated. The power factor of the circuit which excites the transformer ranged from a very low value for the feeblest coronas to 50-70% for the most intense discharges.

The material as well as the size of the wire produced changes in the discharge with corresponding changes in the chemical reactions. A platinum wire was at first used because of its supposed chemical inertness, but platinum is a material which has been found to be one of the most active catalytic substances known. Its catalytic properties seem to depend upon surface absorption and it has been noted that with continued use, as in the oxidation of ammonia, it becomes, apparently, badly corroded. This is, of course, not a true corrosion but a very large

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[7] A wax that will withstand the action of ozone and oxides of nitrogen and yet possesses desirable mechanical properties, is made by melting 5 parts of rosin, adding 3 parts of red sealing wax and then stirring in 2 parts of beeswax. Harding and McEachron, J. Am. Inst. Elec. Eng., April, 1920.

increase in the surface.[6] A platinum wire that had been used as an electrode for corona work was found to have suffered similarly. And with the increase in the surface there was a notable increase in a "lag

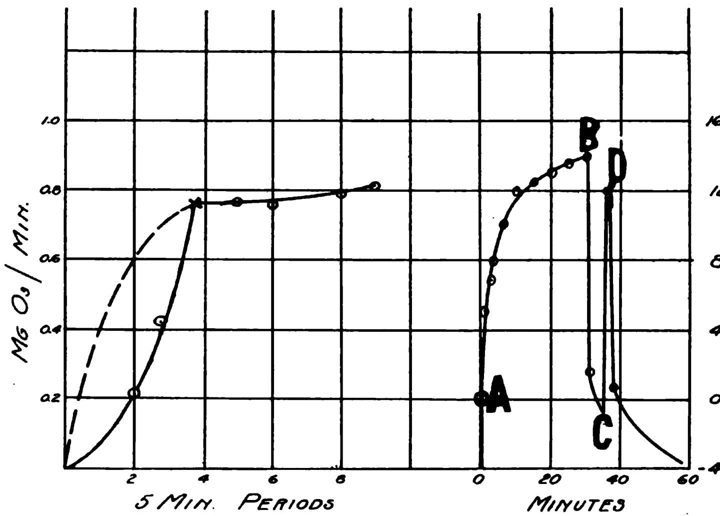

FIG. I. FIG. II.

Fig. I. The "lag effect" due to a platinum wire. A continuous discharge was passed through air flowing at the rate of 190 cc. per min. so that the air in the tube would be renewed in 18 min. The continuous line indicates the actual results for successive five min. periods. The break in this curve occurs with the elimination of the lag effect. The dotted curve shows the normal course of ozone production without any complicating lag effect.

Fig. II. Evidence of an "ionization pressure". The discharge was passed through enclosed air and the pressure was followed by a manometer containing a pure paraffin oil. At A and C the current was turned on and at B and D it was turned off. The jumps are too great to be caused by the rise in temperature.

effect". In Fig. 1 the continuous line follows the actual results obtained in a typical run. Air was passed through the apparatus continuously at a rate of 190 cc. per minute, so that the air in the tube was replaced every 18 minutes. After five minutes of discharge the outcoming air was analyzed for ozone during the second five-minute period in one analysis apparatus and during the third five-minute period in another apparatus. Average yields of ozone per minute during each five-minute period are given. The air that comes out of the tube at first contains less ozone than after it has had a chance to come in contact with the discharge during its whole passage through the tube. Because of the very marked electric wind the effect of any slower rate of flow along the walls than in the middle was largely eliminated.

[6] *Ibil*, p. 2593. A considerable amount of material is accumulating in this laboratory as to the properties and nature of this lag. It will be assembled in a separate publication. For the illustration of the charge on the surface of platinum see Rideal and Taylor, Catalysis in Theory and Practice, Longmans Green & Co., 1919.

The longer the time spent in the discharge the greater the concentration of the ozone, but, owing to the reverse decomposition of the ozone, which occurs simultaneously, the increase in ozone concentration with time should be logarithmic as indicated by the dotted curve. The lag effect has operated against ozone production at first.

An iron wire was also found to be unsuitable because of the large magnetic losses with high-frequency currents. A copper wire was found to be much more suitable, although it became gradually oxidized and covered with more or less nitrate with some "lag effect", although much less than with platinum wires. Aluminum was found to be the best material for ozone production.

An interesting "ionization pressure" has been noted at the University of Illinois by Kunz and his students.[7a] The same effect was observed with the high-frequency corona. In Fig II are plotted some results. The discharge was passed through enclosed air and the pressure changes were followed by means of a manometer filled with the purified paraffin oil called "stanolax". At A the discharge was started and stopped at B; after three minutes it was started again at C and at the end of one more minute of discharge was again discontinued. The sharp breaks are mostly due to the ionization pressure. They are much too sharp and extended to be caused simply by the heating of the gas. At the end the pressure drops below that of the atmosphere, indicating some kind of condensation reaction such as ozone formation.

Typical results are given in Figs. III, IV and V. In Fig. III a No. 33 copper wire was used and the data for one spark gap width

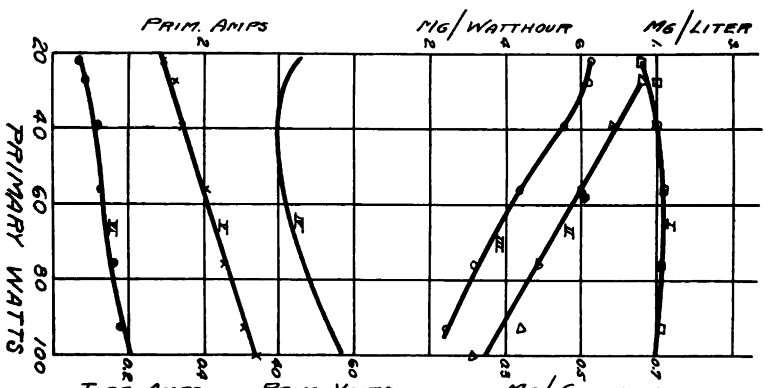

Fig. III. A No. 33 copper wire was placed co-axially in an aluminum tube. The air flow rate was 280 cc. per min. The spark gap-width was 1.2 mm. Six variables are plotted against the gross primary watts as abscissa. I. gives the concentration curve in mg. per liter (g. per cu. M.). II. expresses the yield of ozone in mg. per coulomb of current flowing into the discharge tube. The efficiency of ozone production is plotted in curve III. in terms of mg. per watt hour (g. per kilowatt hour). The other three curves give the electrical readings: IV. for the primary volts; V., the primary amperes and finally VI. gives the amperes of the discharge current as measured by a hot-wire ammeter.

[7a] *Phys. Rev.* 8, 285 (1916); 10, 483 (1917).

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are given. Results with other spacing of the spark gap with this wire and with other sizes of copper wire are essentially similar. With a No. 18 wire of copper or, better, aluminum, the efficiencies are increased two or three times, while the concentrations are often doubled. In this figure the points of interest are the similarity of the curves for primary amperes and for tube amperes, a direct proportionality usually existing. The voltage, on the other hand, as a rule requires a high value in order to start the spark gap and then falls to a minimum. In most cases, the efficiency of the process as expressed in g. per kilowatt-hour (mg. per watt-hour) runs closely parallel to the curve for the yield of ozone per coulomb as calculated from the hot-wire milliammeter in the tube circuit. Usually, also, the concentration is increased at the expense of efficiency, although there are certain conditions where this generalization does not hold. In Fig. III the efficiency is constantly decreasing because in the short distance of the spark gap the tendency of the spark is to change over in characteristics toward a power arc,

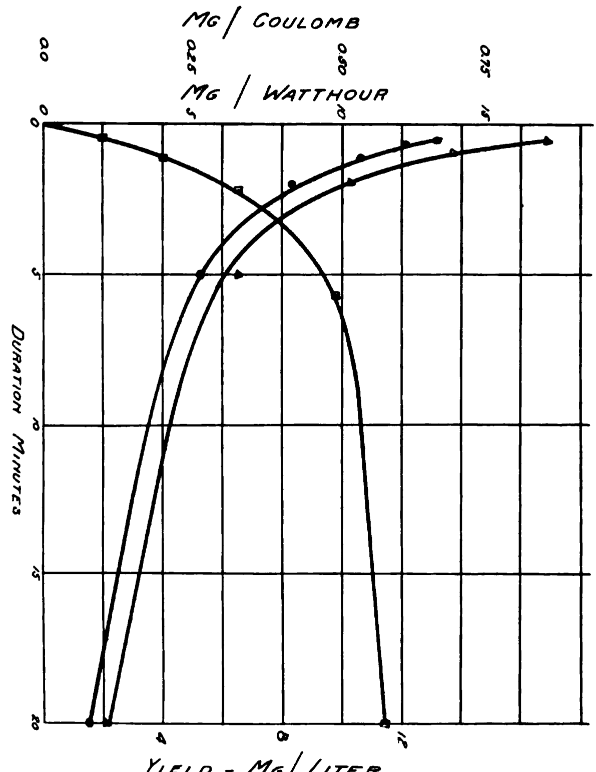


Fig. IV. Enclosed air was subjected to discharge in the same tube provided with a No. 12 wire. The gross power input into the tube was 65 ± 2 watts. The spark-gap was set at 2.0 mm. Note the reciprocal relation of the concentration and efficiency curves, characteristic of *nearly* all chemical reactions in corona discharges.

so that the energy expended in the tube is not proportional to the primary energy. In Fig. IV, where air enclosed within the tube is subjected to discharge for different periods of time, the concentrations are increased with time but at a loss of efficiency owing to the simultaneous decompositions of ozone, such as occurs also with very low frequencies or direct current.[8] In this way, concentrations up to 15 g.

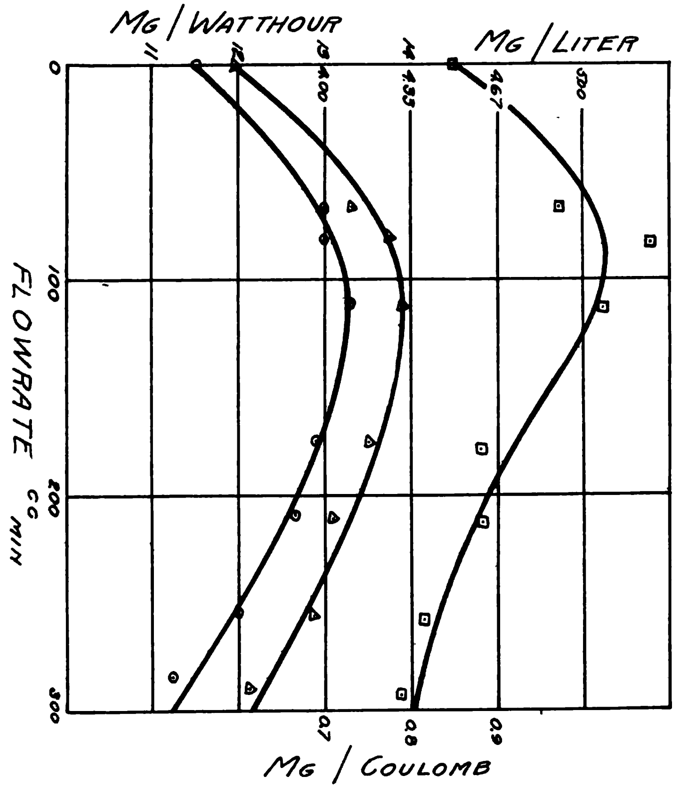


Fig. V. The rate of flow of air through the tube was varied. The length of discharge was 1 min., after which the tube was swept out completely. A No. 18 wire was used and the primary power was 75 2 watts. The spark-gap was set at 2.00 mm.

per cubic meter (mg. per liter) were obtained. In Fig. V an optimum flow rate is indicated for the given conditions. Similar optima have been previously obtained with different types of 60-cycle ozonizers.[9]

The size of wire has a marked effect on the optical and chemical properties of the discharge. Around a fine (No. 33) wire there is a

[8] Chassy, *Compt. rend.* 133, 789 (1901) with a Berthelot ozonizer and 60 cycle current. Anderegg, *loc. cit.*, gives curves for a direct current discharge in oxygen. The shapes of these curves have been checked by A. C. Grubb and J. K. Stewart working independently in this laboratory with current rectified by a kenotron.

[9] Ray and Anderegg, *J. Am. Chem. Soc.* 43, 967-78 (1921), observed an optimum flow rate with the 60 cycle discharge in apparatus A. It was also noted with the very large apparatus E for both ozone and nitric acid production.

weak, nearly uniform glow extending only 4 or 5 mm. from the wire before it tends to break into a spark. With No. 24 wire, fine streamers or brushes are noticeable which become the chief characteristic of the discharge around a No. 18 wire. A No. 12 wire was tried, but the effect was to reduce the radius of curvature so much that sparks were the only form of discharge which could be produced.[10] A No. 16 wire gave the same effect, but, remembering Vosmaer's experiments on space distribution,[11] a number of small points were filed on this wire from which magnificent brushes would be thrown out sometimes to distances estimated as half of the radius. The resonance range under these conditions is narrow and easily overstepped, so that while the discharges most brilliant optically and most effective chemically occurred around a No. 16 wire with points, yet very small surges of power tended to throw them over into sparks with greatly diminished yields. Better total yields are obtained with smaller wires, thus sacrificing erratic for more reliable, although less intense, effects.

Under the best conditions ozone was produced at an efficiency of from 15 to 17 g. per kilowatt hour calculated on a basis of gross power input. No attempt was made to determine the efficiency of the process on a basis of the power delivered from the secondary of the transformer because of the uncertainty in obtaining the tare of the transformer. However, certain considerations indicate that it had a rather large tare, so that with a properly designed transformer the efficiency would have been doubled, or possibly trebled. The loss of energy in the spark gap varied, of course, with conditions. To determine the value the spark gap was enclosed within a water-tight container and immersed in a large calorimeter which had been calibrated with electrical energy. The results at 80 and 110 watts gross input indicated a loss of the total energy supplied to the transformer of 12 and 15%.

The concentration of oxides of nitrogen produced in the corona discharge was 0.005-7% by volume. For every molecule of nitric oxide formed there were produced from 70 to 90 molecules of ozone. When, however (as around a No. 16 wire), a spark played more or less intermittently, the concentration of oxides of nitrogen as well as their ratio to ozone was materially increased. Two runs were made with a discharge in which almost continuous sparking predominated, accompanied by some corona. With a gross input of 120 watts, 41 mg. of nitric acid was obtained in 20 minutes at a flow rate of 95 cc. per minute, so that the concentration was about 0.8% by volume (21 mg. per liter). A 40-minute run at a flow rate of 200 cc. per minute produced 90 mg., reducing the concentration nearly half. The efficiency in each case was a little more than 1 g. nitric acid per kilowatt hour. This method offers little promise as a means of nitrogen fixation under these conditions but might be effective at high temperatures.

[10] The larger wire increases the capacity and tends to throw the circuit out of resonance. With the reduction in radius of curvature of the smaller electrode, the condition of parallel plates is approached.

[11] Vosmaer, Ozone, Van Nostrand, 1916, pp. 56-64. Incidentally, this question of space distribution has resulted in a very larger variety of possible modifications, many of which have been patented.

It has been thought[12] that one of the benefits of a high-frequency discharge might be in setting up so great a vibration with the molecules as to loosen the bonds so that new combinations might take place. A simple calculation would show that the intensity factor of this form of energy is much too small to have appreciable effect in any way except, possibly, upon the loosest of secondary valence combinations. This resonance result must not be confused with the results produced by ionic bombardment of molecules in the large voltage gradients of the corona discharge; nor should it be confused with the very real chemical action of the ultra-violet radiation accompanying any corona discharge.

SUMMARY.

1. This study of the production of ozone in a high-frequency corona discharge indicates that it is governed by the same laws that control its production in either low-frequency or direct-current corona discharges.
2. With the use of high frequency, the discharge apparatus itself is simplified through elimination of any dielectric. This point is of especial value for high temperature work.
3. On the other hand, the apparatus for supplying the electrical energy is much more complicated than for low frequency. This results in greater first cost and in increased energy losses, with consequent decreased efficiency.
4. The conditions which give the most intense discharge with greatest ozone production narrow the resonance range so that small surges of power tend to shift the discharge from corona to spark.
5. The high-frequency discharge is unsuitable for the oxidation of nitrogen. Where ozone is desired, the rather low concentration of oxides of nitrogen is an advantage, but even in the spark discharge the amount of nitrogen oxidized indicates a very low efficiency.
6. In order to use additional discharge units, it would be necessary to "retune" the high-frequency circuits.
7. Even a frequency of a million and a half cycles per second would have little, if any, effect in loosening the chemical bonds.
8. Some evidence is given of a "lag effect" when platinum wires are used.
9. The existence of an "ionization pressure" is indicated in a high-frequency corona discharge.

[12] L. B. Cherry, *loc. cit.*, offers this explanation. But consideration of the energy of the radiation needed to activate carbon compounds indicates that it requires a frequency of 10^{14}-10^{15}, an order of magnitude quite different from the value of 10^{5}-10^{6} cycles per second of the wireless waves set up in his discharge apparatus.

Ozone in Ventilation: Revivification of Mice.

F. O. Anderegg and R. H. Carr.

There has been a considerable amount of discussion as to the value of ozone for ventilation. A summary of the situation was presented before this academy a year ago.[1] The work to be described here is a direct outgrowth of that report and describes some experiments to obtain direct evidence as to the value of ozone physiologically. In view of the success of Dr. Cunningham,[2] of Kansas City, in treating a great variety of diseases by the use of a tank in which the patient spends several hours each day at a pressure of some 15 pounds, it seems desirable to secure evidence as to whether the use of an activated form of oxygen might be beneficial. Some experiments of James Todd,[3] of Pittsburgh, in this connection are of interest.

In the work here described advantage has been taken of the fact that a mouse will die when left in contact with its own exhalations for a sufficient time. This period will vary with the weight, vigor, etc., of the mouse. By placing mice of equal liveliness in filter flasks and then drawing a slow stream of air through the bottles in series, the mouse in the last bottle would be expected to succumb first. In an actual experiment, some divergence is, of course, noted, caused by variations in individual mice. The procedure was to draw air at the rate of 25-50 cc. per minute through 8 or 10 bottles, each containing a mouse, until the mice in a larger number of the bottles exhibited marked lethargy. Then ozonized air was drawn through the bottles in the opposite direction and the revivifying effect noted. Different concentrations of ozone were used. The results obtained so far are rather of a qualitative than of a quantitative nature. To make them quantitative will require a large number of mice so as to largely eliminate individual variations. Sufficient mice for this purpose are being accumulated.

Certain preliminary conclusions may be drawn at this time. Mice which have become rather sick as a result of breathing their own exhalations can be revived by the use of ozone. The greater the concentration of ozone, or the greater the flow rate of ozonized air, the shorter the period of convalescence. On occasion, certain mice have succumbed completely to the poison, and these, of course, could not be revived. The revivifying effect of ozonized air was much greater than that of air free from ozone. The action of ozone seems to be to eliminate the poisonous exhalations by oxidation. Also, when drawn into the lungs, it tends to be selectively absorbed by the blood so that the oxidation of waste material throughout the system is accelerated. With

[1] These Proc. 1920. pp. 271-3.

[2] Floyd L. Parsons. Everybody's Business. Saturday Evening Post, April, 1921.

[3] Experiments with Oxygen on Disease. James L. Todd, New Era Printing Co., Lancaster, Pa., 1916.

the increased removal of waste and poisonous substances from the body, the animal begins to recover. When the ozonized air is started, it passes first into a bottle which contains a rather large amount of foul gases. Then, unless the flow rate is considerable, very little ozone will reach the second bottle. To make a fair test, ozonized air should be drawn directly into each bottle and the time required for recovery noted.

Summary.

Mice which have been poisoned more or less badly by their own exhalations may be brought back to their usual activity by ozone in concentrations estimated as from 1 to 10 parts per million.

Purdue University.

Ozone as a Bleaching Agent in Steam Laundries.

F. O. Anderegg.

In Europe the application of ozone to various commercial uses has been much more successful than in this country. Thus we see great ozone installations for the purification of the city water at Paris and many other cities. Notable application of ozone to the ventilation of the London Subway is being made, while the French use considerable amounts of ozone in the synthesis of various perfumes and other high-grade organic chemicals.

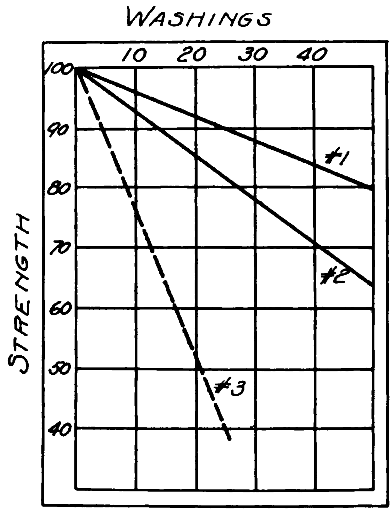
In Germany there are two firms which produce ozonizers suitable for use in steam laundries. One, the Ozongesellschaft m. b. H., is a branch of the Siemens-Halske firm, which is connected with the famous A. E. G., the great electrical trust. This concern uses the most modern modification of the Siemens tube, which has been used extensively for ozone production for a great many years. Another company has concentrated on the application of ozone to laundries. This firm goes by the name, Aktiengesellschaft fuer Ozon-industrie.

Both of these companies advertise in the most glowing terms as to the wonderful merits of ozone as a bleaching agent. Claims are made of great saving in soap, water, overhead, labor, in addition to considerable improvement in quality through the use of ozone as a

Tests made on cotton goods by the Staatlichen Materialpruefung-samtes of Berlin-Dahlen. No. 1 is for ozone bleaching in cold water. No. 2 gives similar data for ozone in hot water, while No. 3 shows the harmful effect of typical peroxide bleaches which has reduced the strength (festigkeit) of the goods to 40% in 25 washings.

bleaching agent. It is stated that the most delicate material is unharmed by their ozone bleaching. Shirts are supposed to have the white part bleached purer white while the colored pattern is brightened by this treatment. Now ozone acts on most organic material with which it comes in contact so that it is surprising that the colored part should not be bleached also! On the other hand, tests made at Berlin-Dahlem by the Staatliches Materialpruefungsamt, using the Goedicke apparatus of the Aktiengesellschaft fuer Ozon-industrie showed that with ozone the goods lasted very much longer than with chlorine bleach material. Samples of cotton cloth were treated and observed after every ten bleachings. A decrease in strength was observed while the weight and stretching were both increased. The cotton goods still maintained 80% of their strength after 50 treatments in cold water, 64% in hot water, while 25 bleachings with chlorine water reduced the strength to a very small value.

As to cost, there is considerable doubt also as to their claims. The use of Javelle water as practised today in up-to-date laundries is a very small item. The interest on the cost of an ozone installation in addition to the power consumption, although it amounts to but a few



watts, bring the cost of ozone just about to a level with that of Javelle water. There remains only the question of quality. At present, it is frequently remarked that home-washed clothes outlast laundry-washed clothes often two to one. Part of this is due to the stronger soaps, soda, etc., used in the laundry, part to the greater mechanical agitation perhaps, and part to bleaching methods. The housewife does not usually use a chemical bleach, but gets the natural effect of the sunlight and moisture in producing sufficient active oxygen in one form or another to give a very beautiful bleaching action. If ozone has the property of emulating sunlight bleaching its use would certainly be desirable.

Heinz & Co. of Berlin are treating newly-woven linen in two revolving drums with ozone to remove the yellowish tinge very successfully. These drums were built by the Aktiengesellschaft to order and their successful operation resulted in the application of ozone to laundry bleaching in several laundries. This is a development of but the last two or three years and ozone may well have found a real use in this field.

Deut. Waescherei Ztg. 22, No. 6, pp. 594-595 (1920); 23, No. 9, p. 328 (1921); 23, No. 15, p. 587 (1921).

Purdue University.

Some Characteristics of a Siemens Ozonizer.

Karl B. McEachron.

For a number of years the Engineering Experiment Station at Purdue University has been conducting an investigation entitled, "The Fixation of Atmospheric Nitrogen by the Silent Discharge Process." In the course of this work a study has been made of certain types of discharge tubes, and very brief discussion will be given here of some of the results of the tests on the Siemens tube.

Discharge Tube and Absorption Apparatus.

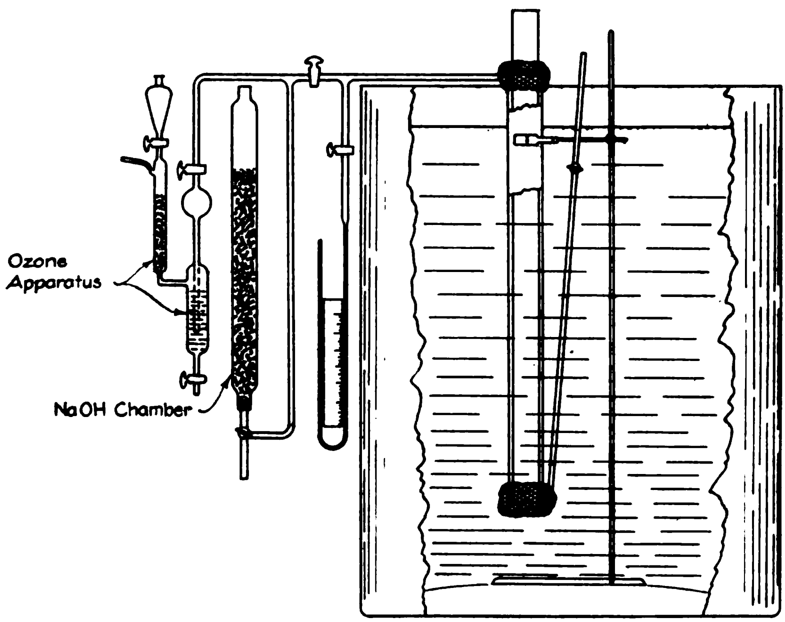


Fig. 1.

An idea of the construction of this tube may be gained by reference to Fig. 1, which shows the tube supported by a ring stand in a tank of cooling water. The tube was constructed of two glass tubes arranged concentrically, the inside one being sealed at the bottom. The space between the two tubes was closed at either end with paraffine, and small tubes so placed that air could enter at one end of the annular space between the tubes and leave at the other end. The radial length

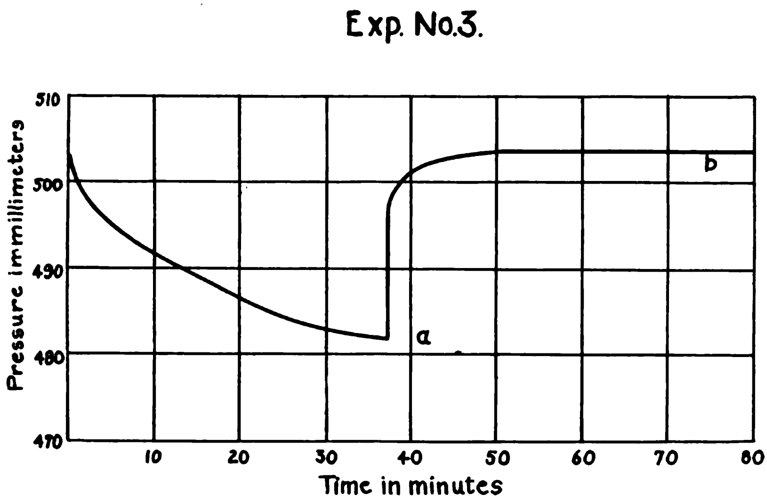
of the annular discharge space was approximately 3 mm., the outside diameter of the inner glass tube being 33.5 mm., and the length of the discharge space, 50 cm. The volume of the discharge space was found by actual measurement to be 166 cc. The inside tube was filled with acidulated water, and this together with a spiral of No. 18 copper wire placed inside the tube acted as the high tension electrode. The water surrounding the tube, which was made conducting by the use of NaCL, was grounded through the medium of the metal containing tank connected to the ground. A spiral of wire was wound around the outside of the discharge tube and connected to ground to insure even distribution of voltage over the entire length of the tube.

Absorption apparatus consisting of broken glass tubing placed inside a tower was connected as shown in Fig. 1. Sodium hydroxide was used in most cases as the absorbing liquid. In some cases the gases were passed through a KI solution from which the ozone yield could be determined by titration with sodium thiosulphate. The inlet and outlet tubes were provided with stop cocks so that the tube could be completely closed and the pressure of the gas in the discharge tube measured by the mercury manometer. Alcohol thermometers were placed in the liquid inside the inner tube of the discharge tube and in the cooling water surrounding the tube. Means were provided whereby dry air could be passed through the discharge space, the air having been dried by the use of sulphuric acid, after which it passed through a chamber containing soda lime.

Two sources of power were provided for producing the required electric potential to break down the air in the space between the two tubes, one of these being a large induction coil and the other a high voltage transformer. The induction coil was operated from a 110-volt direct current source and was provided with a rheostat in series for varying the high tension voltage. This coil is capable of delivering a spark between needles of more than 30 cm. in length. The high tension transformer, rated at 50 kva. 200,000 volts, was connected to an alternator giving practically a sine wave. This transformer has been arranged so that the current in the secondary winding may be read directly. The high tension voltage was determined by calibrating the tertiary coil, with which the transformer was provided, against the sphere gap standard of the A. I. E. E.

Tests on Enclosed Volumes of Dry Air.

All of the tests which will be reported in this paper were made upon enclosed volumes of dry air, using either the induction coil or the high tension transformer. Only tests which are more or less typical will be given here, and represent but a small part of the total number of tests made. Correction for pressure change due to increase of temperature as the run progressed was not made, although in many cases the temperature rise curve is shown, this temperature being invariably that of the inner electrode. The temperature of the outside of the tube did not change materially on account of the large body of cooling water which was agitated frequently.



a-5.6 vol. % NO b-.6 vol. % NO

FIG. 2.

The curve in Fig. 2, taken from Spiel,* who made tests on a Siemens tube with induction coil supply, shows a decrease in pressure with time, until a reversal point is reached, after which the pressure rises rapidly, coming back to nearly if not quite the original pressure.

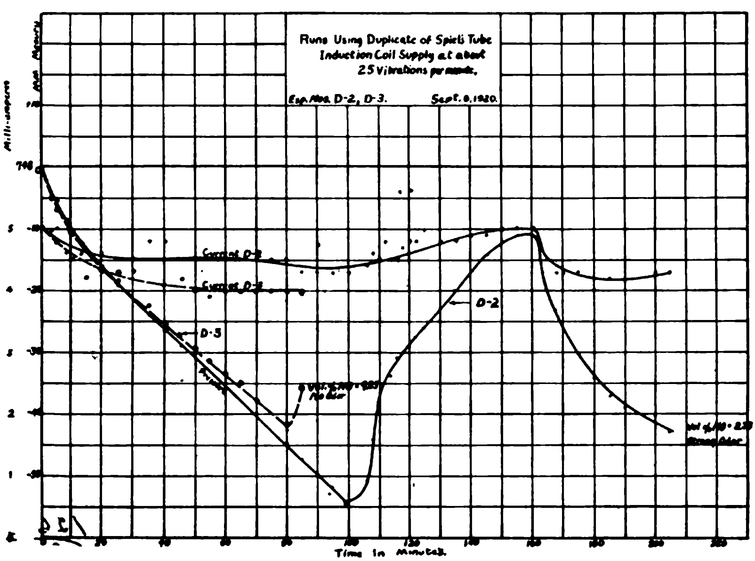


Fig.-3.

* The Formation of Nitric Oxides by the Silent Electric Discharge in a Siemens' Tube, by Hugo Spiel, Doctor's Thesis, The Technical High School; Vienna, 1909.

At the reversal point a concentration of 5.6 per cent calculated as NO was obtained, while at the point b after the pressure had become constant concentration of only 0.6 per cent NO was found. Spiel concludes that no lower oxides of nitrogen are formed, only N_2O_4. Spiel determined the concentration at the reversal point by making a second run holding all the conditions as near like the first run as possible. It has been found, however, by plotting the data which Spiel gives, that the pressure time characteristic was not the same for both runs, and this condition is one which the author of this paper has found to exist in all the work done at Purdue with enclosed volumes of air.

Characteristics, different from anything reported by Spiel, appeared when the first run was made on the discharge tube, after being set up, using the induction coil for power supply. The changes in current and pressure with time may be seen by reference to Fig. 3. The current shown is the actual current and was measured in the ground connection of the cooling tank. The full line curve marked D-2 represents the first run, which was continued for 205 minutes. The pressure seemed to go through a cyclic change which also appeared in the current to some extent. A second run (D-3) was made, giving quite different current with a reversal at a higher pressure coming 20 min-

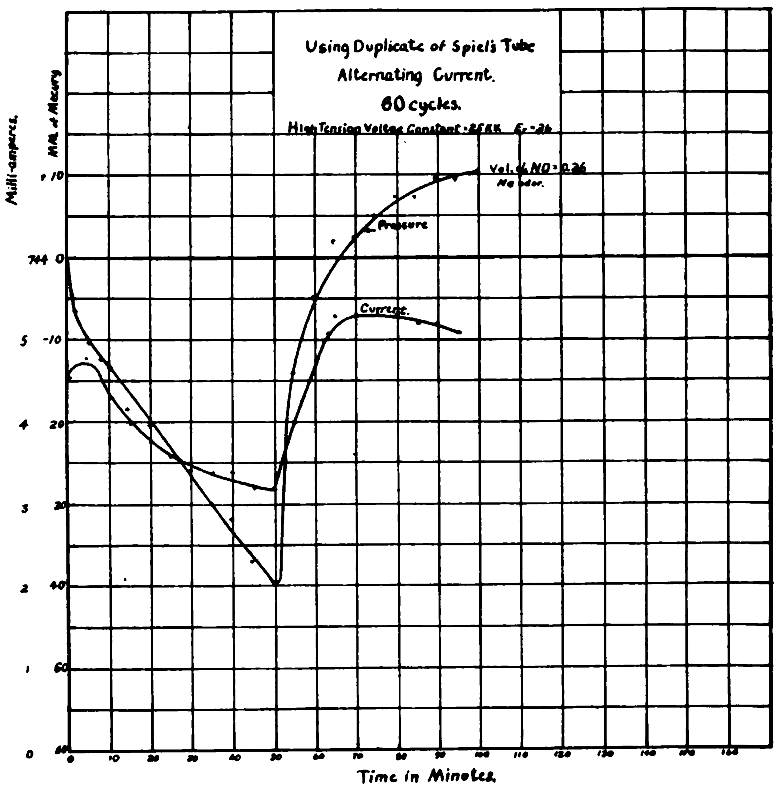


Fig.- 4.

utes sooner than in the first run. The concentration of NO at the end of the first run, at a pressure of —42.5 mm. was 2.3 compared with a concentration of 9.35 per cent NO at —42.0 mm. Here the pressures are practically the same and yet the products are quite different. Several runs were made later in the attempt to check the cyclic change in this run, but without success.

Another run under the same conditions was made and stopped at the reversal point, which occurred at 130 minutes with an NO concentration of 9.9 per cent, the tube current being 3 milliamperes compared with 4 and 4.5 milliamperes for the first two runs. Although 34 runs were made, following these first two runs, yet in every case the concentrations were much lower than in these first two runs.

Using the transformer supply, the curves shown in Fig. 4 were taken, the high tension voltage being held constant. The same reversal occurred here as before, but the pressure increased very rapidly after reversing and at the end of the run a concentration of 0.363 per cent NO was obtained. The second test with alternating current (D-8), reversed at a pressure about 7 mm. higher than did D-7, but the reversal in both came at 50 minutes. The concentration at reversal with alternating current was 2.48 per cent NO, which is considerably less than was obtained with the induction coil. The variation of the tube current should be noted since the current curve follows the pressure curve more or less in shape. Another run with the transformer was made at 31 cycles, which was as near the 25 vibrations per second of the induction coil as could be obtained. The pressure in this run reversed at 53 mm. below the initial pressure of 740 mm. after an exposure to the discharge for 110 minutes. The concentration at this point was 3.21 per cent NO.

From these results it is clear that the yield of nitric oxides, which may be discovered by the titration of NaOH for the determination of acid formed, is not proportional to the pressure decrease as might be expected. To get some idea of the concentration for different times of exposure to the discharge with both the induction coil and the alternating current, a series of runs were made which are tabulated in Table I.

TABLE I.

No. D—	Length of Run (min.)	Pressure Decrease at end of run (mm.)	Percent NO. at end of run	Concentration	
				per mm.	per min.
		Induction coil runs—Frequency—25			
13	10	—12.5	0.073	0.0058	0.0073
14	20	—16.5	1.00	0.062	0.05
14.5	40	—25.5	1.88	0.074	0.047
15	60	—34.0	2.12	0.082	0.035
		Alternating Current Runs—Frequency—31			
10	10	—12.0	1.52	0.127	0.152
11	20	—17.5	1.91	0.109	0.09
12	40	—26.0	2.11	0.081	0.07

Although the average current for the alternating current runs listed in Table I was less than for the induction coil runs, yet the

concentration per millimeter, and per minute, are higher, indicating that under the conditions examined, the use of alternating current increases the speed with which the nitric oxides are formed. It should also be noticed that the concentration per millimeter pressure change increases with the length of run using the induction coil, but decreases with alternating current, indicating that short alternating current runs are advantageous.

Several runs were made to discover, if possible, the reason for the lack of consistent results, but the results were erratic, the pressure reversal varying both as to time and pressure decrease. The yields of nitric acid were different with each run and seemed to vary erratically also.

The usual practice before beginning a run was to sweep out the tube with dry fresh air. On one occasion this sweeping out process was omitted and the results were quite surprising. The tube had stood over night, the products of the last run having been blown out the night before. Instead of decreasing, the pressure increased 17 mm. in 50 minutes, the titration at the end of the run showing only a trace of nitric oxides and no odor of ozone could be detected. Two

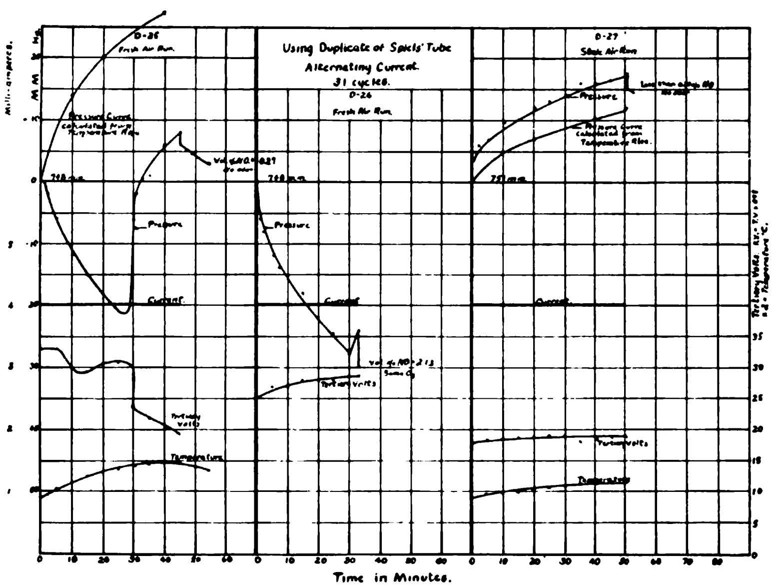


Fig.-5.

other runs, D-25 and D-26, were made under all the same conditions, except that the tube was swept out with fresh dry air just before applying the voltage. The curves showing the characteristics of these three runs are found in Fig. 5.

The pressure time characteristic with fresh air (run D-25) shows three distinct parts, viz., the pressure decrease, the pressure increase to initial pressure and the pressure rise after reaching the initial pressure. A very small yield of NO was obtained from this run, while

more than eight times the concentration of NO was obtained at the reversal point on run D-26, which was made under the same conditions as D-25.

Several runs were made to determine whether or not the pressure rise could be duplicated, and it was found that it could be reproduced as desired, using either the induction coil or the alternating current. Whether or not the same result would have taken place in a new tube of different construction is not known.

The experiments made on fresh air compared with those made with air which has stood in the tube for a considerable period show a very marked change. When the air is not fresh in the tube, but has stood for some time in the tube following the last application of the high voltage discharge, the pressure rises when voltage is applied, and no appreciable quantity of ozone or nitric oxides are to be found. The corona discharge is more noisy and appears to consist of many sparks and points. This condition is much like that after reversal when fresh air is used, for immediately upon reversing the discharge changes from a quiet blue glow to noisy streamers and condensed discharges, which condition increases as long as the pressure increases. Although the shape of the pressure rise curve differs somewhat when using stale air compared to the rise above the initial pressure when using fresh air, yet, all the evidence obtained goes to suggest that in some manner the air standing in the tube is carried through the equivalent of a reversal and subsequent pressure rise. The air standing in the tube may well be affected by some traces of the products of the previous run, this action being catalytic in its nature. Such traces may remain occluded in the glass or in a very dilute state in some air pocket.

Run No. D-28 was made in an effort to secure more information concerning the way in which the contamination took place. This run followed D-27 with an interval of 23 hours. The air was swept out of the tube following D-27 in the usual manner, allowing about 15 minutes for absorption. The tube was then closed up for 3 hours, after which fresh dry air was blown through at a rapid rate for 3 hours. The tube was again closed up, and the next day, after an interval of 17 hours, run D-28 was made. Reversal took place at 30 minutes after the pressure had decreased 28 mm. Titration at this point gave a concentration of 0.4 per cent NO, while but a trace of ozone was observed.

From this experiment it appears that the effect of contamination is reduced by sweeping out the products after a run, using a large quantity of air. In case the tube stands for a considerable length of time, even though the tube has been carefully swept out, the yield is materially affected as in D-28, where the yield was about one-eighth of what it was in D-29, which was a check run with fresh air. Thus, even small traces of the previous runs serve to greatly reduce the yield. Curves showing the pressure changes for D-28 and D-29 will be found in Fig. 6.

The results from the use of a discharge tube not only vary with the design but also vary greatly with tubes of the same design. A second tube built of pieces of the same tubing and having practically all the same dimensions as the tube described in the first part of this

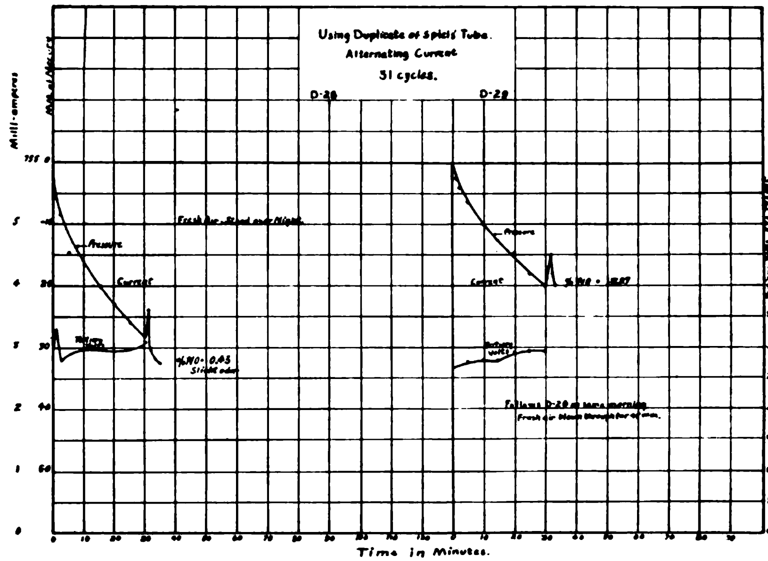


Fig. 6.

paper was constructed. The first test on this tube was made with alternating current and the results may be seen by reference to Fig. 7. The pressure characteristic is very different than any obtained with the first tube. Instead of decreasing rapidly as before, the pressure remained constant for 10 minutes and then began to fall rapidly. For the most part, the points fall on a straight line, which again is very different from any result obtained before. The pressure decreased 114 mm. in 190 minutes, which when corrected for temperature gives a pressure decrease of 143 mm. below the atmosphere. This represents a contraction in volume of nearly one-fifth and yet the NO concentration was only 1.2 per cent, and only a slight odor of ozone. It appears likely that some heavier molecule than we know of at present is being formed. That this must be true will be clear when it is stated that in order to secure such a pressure decrease an NO concentration of 15 per cent would be required if the decrease was due to the formation of N_2O_3 calculated as NO. Such a contraction is not of the same order of magnitude as the one observed in this run.

Several runs were made on this tube in an effort to again secure the great pressure decrease observed in D-37, but although most of the runs showed the same initial characteristic as did D-37, yet reversal came in every case before the pressure had decreased more than 60 mm. The difficulty of duplication of results is one which has been met with continually in the work done on these discharge tubes.

Conclusions Drawn from the Tests.

1. Holding conditions as constant as possible, the pressure reversal points do not check at all closely, and concentration values obtained at the reversal point by stopping a check run can give but approximate values for this reversal point.

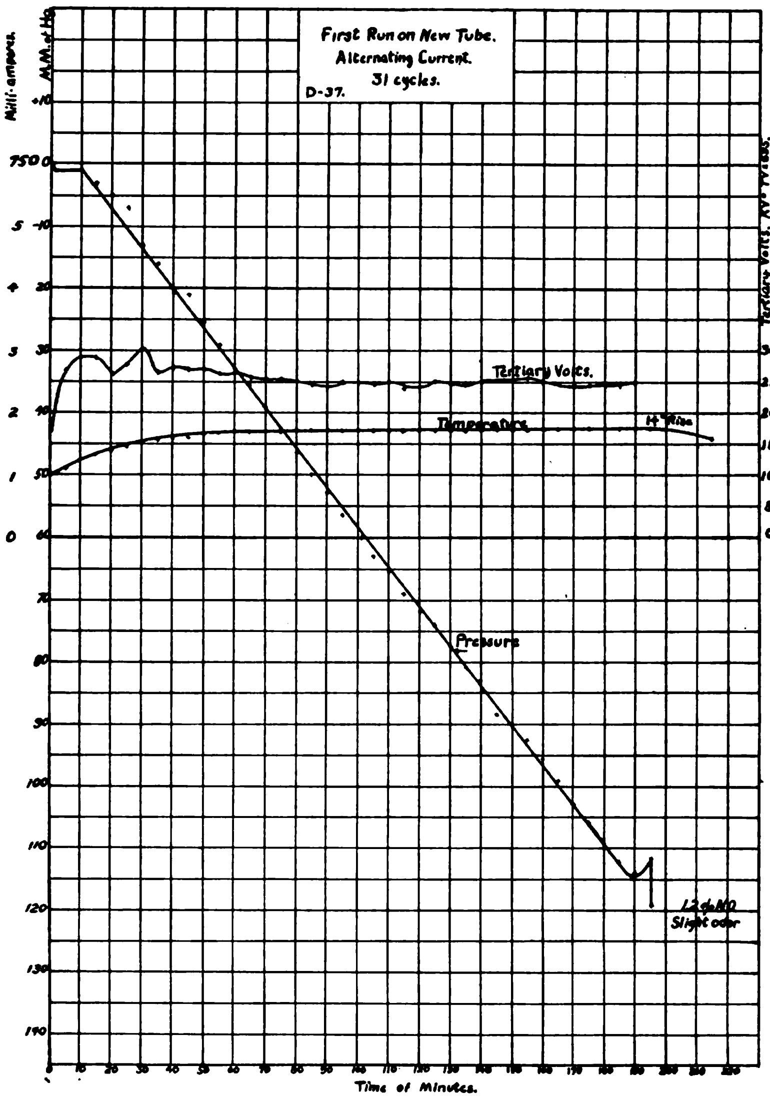


Fig. 7.

2. When air in the tube has been in contact for a considerable period with other air which has been previously subjected to electrical discharge, the usual pressure decrease is modified, the yields diminished, and in case sufficient contamination has taken place the characteristics of the tube changed altogether, the pressure increasing instead of decreasing and the yield greatly reduced or eliminated altogether.

3. While it is true that the discharge is more or less erratic in a given tube, yet there seems to be some foundation for the statement

that different tubes of the same design and of similar materials will yield different results.

4. The usual pressure characteristic consists of four parts:
    1. The pressure decrease.
    2. The pressure increase (usually quite rapid) up to atmospheric pressure.
    3. The pressure increase (having the shape of a temperature rise curve) above atmosphere.
    4. The abrupt pressure decrease when the power supply is disconnected.

Part 4 always occurs; parts 1, 2 and 3 are to be found together when working with fresh air only, while part 3 only will be found when the air has been sufficiently contaminated.

When the pressure is decreasing the discharge is more quiet and, as a rule, the temperature rise less than when the pressure is increasing. The character of the discharge is also quite different after reversal than before, thus indicating a very definite change in the structure of the air. This statement is also borne out by the fact that changes in pressure are accompanied by corresponding changes in current flow when the voltage is held constant.

5. The pressure decrease is not proportional to the nitric oxides absorbed. The pressure decrease is always greater than can be accounted for by the products absorbed, thus indicating the presence of some heavier molecule. It is true that some of the pressure decrease may be due to some of the gas being driven into the glass, but that this would account for the discrepancy observed seems doubtful. Whether this heavy molecule is a combination of O and N or a heavy molecule of O or N it is not possible to state. It is likely, however, that more than one such combination will be found in the effluent gases.

6. Although not conclusive, the data does show that in most cases the pressure decrease with alternating current is more rapid than with the induction coil. The 10, 20, and 30 minute runs indicate that alternating current may also be expected to produce a higher concentration of nitric oxides in a given time, and especially is this true for the shorter periods of discharge.

Complete data showing the results of tests not only on the Siemens tube but tubes of other design, together with much other material of interest relating to the corona discharge, will be found in a bulletin of the Engineering Experiment Station of Purdue University, to be published in the near future.

The author wishes to express his appreciation for the assistance given him in the prosecution of this work by various members of the staff of Purdue University and particularly to Dr. Anderegg.

Engineering Experiment Station, Purdue University.

THE SIMULTANEOUS ELECTRO-DEPOSITION OF LEAD AND LEAD PEROXIDE.

M. G. MELLON and H. F. REINHARD.

PART I—INTRODUCTION.

General. For many years it has been known that one may obtain the deposition of either metallic lead upon the cathode or lead peroxide upon the anode by the electrolysis of an aqueous solution of lead nitrate, depending upon the conditions maintained during the electrolysis. Many experiments under varied conditions have shown that lead may be quantitatively deposited on the anode as the peroxide from a solution of the nitrate containing 10 to 20 per cent nitric acid of Sp. G. 1.35-1.40.[1] A quantitative deposition of the lead in the metallic state has not been accomplished from aqueous solutions of the nitrate except through the addition of other compounds, such as those recommended by Stähler and Alders.[2] They accomplished this by separating the lead as amalgam from a solution of the nitrate (0.0997 g. lead) and of mercuric chloride (0.0855 g. mercury) together with 1 cc. of concentrated nitric acid and 1.5 cc. of phosphoric acid. Also Vortmann[3] states that lead can be quantitatively separated as an amalgam from a solution containing 1.4 g. of the lead salt, 1.2 g. mercuric chloride, 3-5 g. sodium acetate, 1 cc. of a concentrated solution of potassium nitrite, and enough acetic acid to dissolve any white precipitate formed.

In connection with two other investigations[4] lead amalgams were used which were made by electrolyzing a 10 per cent solution of the nitrate with a weighed amount of mercury for the cathode and a platinum foil electrode for the anode. After electrolyzing for 2 to 3 hours with a current of approximately 20 milliamperes, sufficient lead was deposited in the mercury to show a considerable amount of solid along with the liquid amalgam. This solid was taken to be the compound Pb_2Hg, described by Fay and North.[5] A comparatively thick, adherent deposit of lead peroxide was always obtained on the anode. In this previous work a coulometer was included in the electrical circuit, the assumption being that a quantity of lead would be deposited in the mercury cathode equivalent in amount to the metal deposited in the coulometer. Then, knowing the weight of the lead deposited and the weight of the mercury, one could readily calculate the percentage composition of the amalgam. Such a procedure, with a silver coulometer, has been used by Henderson[6] for zinc amalgams, and by Richards and Wilson[7] for

[1] Smith—Electro-Analysis, p. 109 (1918).
[2] Ber. 42, 2685 (1909).
[3] Ibid. 22, 2756 (1891).
[4] Henderson and Stegeman—J. Am. Chem. Soc. 40, 84 (1918). Mellon and Henderson—Ibid. 42, 676 (1920).
[5] Am. Chem. J. 25, 216 (1901).
[6] Phys. Rev. 29, 507 (1909).
[7] Carnegie Inst. Pub. 118, 1 (1909).

amalgams of thallium, indium and tin. Meyer[1] has used a hydrogen coulometer for similar work.

The validity of the above assumption regarding lead has seemed questionable, and the purpose of the present work has been to ascertain, first, the relative amounts of the two deposits; and, second, the relation between each of these amounts and the amount of silver deposited in a silver coulometer placed in the circuit in series with the cells containing the solution of lead nitrate. The latter quantities should enable one to answer the question as to whether there is deposited in the mercury a weight of lead equivalent to the weight of silver deposited in the coulometer, and, therefore, whether one can calculate the per cent of lead in the amalgam from the amount of silver deposited.

Previous Work. Although "Lead most readily of all the elements forms oxide on the anode during electrolysis,[2] there is a considerable tendency for this element to separate from an aqueous solution of the nitrate partly as metallic lead on the cathode and partly as lead peroxide on the anode. Various individuals[3] have noted this division of the lead between the two electrodes and have studied the factors influencing the formation of the two deposits. Electrolysis from a neutral solution gives both the metal and the peroxide. An addition of nitric acid seems to improve the conditions for obtaining the peroxide; for with 15-20 per cent of the acid present, all the lead deposits in this form. Even with these higher concentrations of acid, however, a small amount of metallic lead may deposit, but it gradually dissolves as the decomposition proceeds. Easily oxidizable substances, such as lactose, glycerine, etc., hinder or prevent the formation of the peroxide. Oxalic acid, for example, is said to be very efficient for this purpose.

In this earlier work there is included no mention of quantitative results on the relative amounts of the deposits of metallic lead on the cathode and lead peroxide on the anode, under the different conditions of electrolysis. Any of the quantitative determinations have been made with the aim of separating all the lead, either as peroxide or as the metal.

Present Problem. The object of the present investigation has been the determination of the quantity of lead deposited at each electrode, under varying conditions of electrolysis, together with a determination of the quantity of silver deposited in a coulometer placed in the electrical circuit. This has involved, first, the arrangement of apparatus suitable for the electrolysis; and, second, the selection of satisfactory analytical

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[1] Z. Phys. Ch. 7, 481 (1891).

[2] Mathers—Trans. Am. Electrochem. Soc. 23, 178 (1913).

[3] Luckow—Z. anal. Ch. 19, 15 (1876); Ibid. 22, 485 (1883).
Schucht—Ann. Chim. Phys. (5) 13, 508 ().
Frechland—D. R. P. 140, 317; J. Ber. 9, 660 (1903).
Thomälsen—Chem. Ztg. 18, 1355 (1894).
Vortmann—Ann. 351, 238 (1907).
Gooch and Beyer—Am. Jr. Sci. (4) 25, 249 (1908); 27, 59 (1909).
Fairchild—J. Ind. Eng. Chem. 3, 902 (1911).
Smith—J. Am. Chem. Soc. 27, 1287 (1905).
Tenney—Am. Jr. Sci. (4) 5, 413 (1883).

methods for the determination of the lead peroxide on the anode, the metallic lead in the mercury of the cathode, and the metallic silver in the coulometer.

PART II—EXPERIMENTAL PROCEDURE AND DATA.

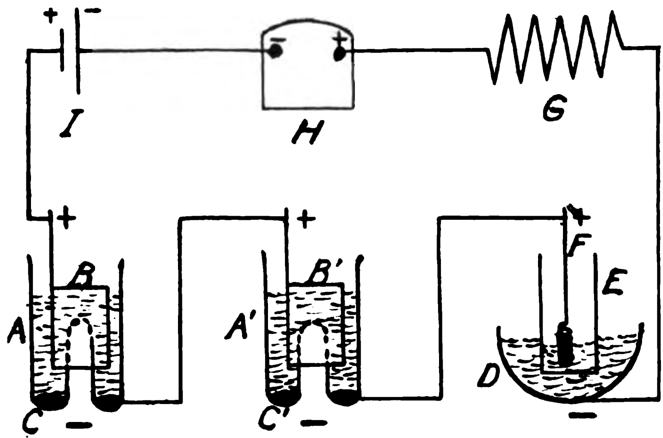

Fig. 1

Apparatus. The arrangement of apparatus used is illustrated by Fig. 1, in which A, A′ represent special glass cells containing the solution of lead nitrate—these were about 6 cm. in diameter and of such a form that 40 g. of mercury easily covered the platinum points in the bottom; B, B′ are anodes of platinum foil 2.5 cm. in diameter and 5 cm. in length; C, C′ are the mercury cathodes, the electrical contact being made with them by means of three short pieces of platinum wire sealed through the glass; D is a platinum dish 7 cm. in diameter serving as the cathode in the silver coulometer; E is the porous cup, 3.5 cm. in diameter, and F the anode of 15 gauge coiled silver wire; G is an adjustable rheostat; H a milliammeter and I a storage cell.

Analytical Methods. The weight of silver deposited was determined by weighing the platinum dish after drying to constant weight at 105° C.

In order to determine the lead in the deposit of peroxide, the original intention was to follow the volumetric method suggested by Scott.[1] This consists in dissolving the peroxide from the electrodes with a hot mixture of 15 cc. of fifth normal oxalic acid and 10 cc. of nitric acid (Sp. G. 1.2) and titrating the excess of oxalic acid with tenth normal potassium permanganate. The end point in the titration with the potassium permanganate proved to be so indefinite that the method was abandoned for a procedure essentially that recommended by Smith.[2]

[1] Standard Methods of Chemical Analysis, p. 240 (1917).
Chwala and Colle—Z. anal. Chem. 50, 209 (1911).

[2] Loc. cit.

This consisted in washing the deposits with water, placing the electrode in a platinum dish, and drying both in an electric furnace in which the temperature was maintained at approximately 250° C. by means of a pyrometer. While wet, the peroxide did not show any tendency to scale off during handling; but as soon as dried, it often did not adhere well. By drying in the platinum dish, any particles falling off were saved, since the dish and electrodes were weighed together.

It was planned to determine the weight of lead deposited at the cathode according to the method of Stähler and Alders,[1] that is, by obtaining the increase in weight of the mercury cathode after having decanted the electrolyte and washed the amalgam with water, alcohol and ether. Although it is stated that this procedure gives very good results, it was not found possible to handle the amalgams in this way without having marked evidence of oxidation on the surface of the amalgam, even with only a few hundredths of a gram of lead present. Sometimes a black scum formed on the surface, which was easily lost in the washing by decantation. Some of the preliminary results were obtained in this way, but the method was changed for one proving more satisfactory.

The procedure adopted consisted essentially in the replacement of the lead in the amalgam by another element, thus bringing the lead into aqueous solution from which it could be precipitated.[2] This was accomplished by washing the amalgam with water by decantation and then adding 25 cc. of a 10 per cent solution of copper nitrate. The solution remained on the amalgam from 15 to 24 hours, after which it was decanted and the resulting amalgam washed with water. Copper is less soluble in mercury than lead, and most of the determinations showed considerable brownish-red material in the beaker containing the amalgam, after standing in contact with the copper nitrate for several hours. This was found to be largely copper, along with some mercury, and the solution was always filtered from this precipitated matter. To the filtrate two or three drops of acetic acid were added, the solution heated to somewhat less than boiling, and the lead precipitated with potassium dichromate. The precipitate was handled and weighed according to the directions of Scott.[3]

General Procedure. The arrangement and manipulation of the silver coulometer followed rather closely the suggestions of Richards and Anderegg,[4] a porous porcelain cup and recrystallized silver nitrate being used. All the precautions noted in their papers were not followed, such as corrections for the amount of electrolyte included in the cathode deposit and protection from dust during electrolysis, since the nature of the present work did not seem to warrant it.

Each determination was made by placing 30 to 50 g. of mercury in each of the glass cells and adding 100 cc. of the solution of lead nitrate to be electrolyzed. The platinum foil anodes were suspended in the electrolyte about 1.5 cm. above the surface of the mercury. In-

[1] Loc. cit.

[2] Mellon and Reinhard—See following paper.

[3] Standard Methods of Chemical Analysis, p. 236 (1917).

[4] J. Am. Chem. Soc. 37, 7 675 (1915).

side the platinum dish serving as cathode for the coulometer, and about 0.5 cm. above the bottom, the porcelain cup was suspended. The silver wire in the form of a spiral was lowered close to the bottom of the cup. After filling the dish nearly full, and the cup slightly below this level, with a 5 per cent solution of silver nitrate, the current was allowed to pass from 1 to 3 hours. At the end of this time, the solutions in the three cells were siphoned off simultaneously, being replaced with distilled water until the ammeter in the electrical circuit indicated practically no current passing. The weights of silver and lead deposited were then determined according to the methods already outlined.

The solution of lead nitrate used as electrolyte for the determinations reported in Table II was made by dissolving an amount of the salt in water to produce an approximately 10 per cent solution. For the second series, the solution was made by diluting 40 cc. of concentrated nitric acid to 1 liter with the previous solution; and the third solution was made in the same way, using 80 cc. of the nitric acid.

The value for the lead equivalent of the silver deposited was obtained by multiplying the weight of the silver for each determination by the ratio obtained in dividing one-half of the atomic weight of lead (207.20) by the atomic weight of silver (107.88), this ratio being 0.9603. The factor used for lead in lead peroxide was 0.866.

The quantities reported for lead as lead peroxide and for lead as lead amalgam are the average of the two cells run in each experiment. The values reported as variations from the average indicate the amount by which each determination varied from the average of the two. The amperage showed some variation during the electrolysis, and the values recorded are taken as the average. Table I includes some preliminary results, and Table II those obtained in the later work.

TABLE I.
Deposition of Lead from Aqueous Solutions of Lead Nitrate.

No.	Time in Hours	Milliamperes	Lead as Peroxide	Lead as Amalgam	Ratio of Anode Lead to Cathode Lead
1	3.0	20	0.2383	0.2329	1.0232
2	3.0	20	0.2489	0.2294	1.0850
3	3.0	20	0.2505	0.2384	1.0508
4	3.0	24	0.3098	0.2979	1.0399
5	5.5	10	0.1993	0.1870	1.0657
6	4.0	14	0.2099	0.1932	1.0864
7	4.0	19	0.3229	0.3040	1.0621

The investigation reported in this paper was begun at The Ohio State University in 1919 by C. C. Curran under the direction of the senior author. The results in Table I, obtained at that time, when compared with those in Table II, show the effect of employing more refined methods of analysis.

In this earlier work a copper coulometer was used, but the results obtained with it indicated inaccurate manipulation. The lead peroxide was weighed after drying at 105° C.; and the metallic lead was obtained from the increase in weight of the mercury cathode, after being washed with water, alcohol and ether. These determinations include

TABLE II.
Deposition of Lead from Aqueous Solutions of Lead Nitrate

No.	Time (Min)	Amperage	Pb Equiv. of Silver	Lead as Peroxide	Variation from Ave. of 2 Cells	Lead as Amalgam	Variation from Ave. of 2 Cell	Ratio of Anode Pb to Pb Equiv. of Silver	Ratio of Cathode Pb to Pb Equiv. of Silver	Ratio of Anode Pb to Cathode Pb
					(Series I—No. HNO_3)					
				0.2031				0.9936		1.0026
1	70	44	0.2044	0.2062	±0.0001	0.2025	±0.0000	1.0088	0.9907	1.0187
				0.2963				0.9858		1.0018
2	107	44	0.3006	0.3008	0.0004	0.2958	0.0002	1.0008	0.9840	1.0171
				0.1567				0.9831		1.0021
3	51	44	0.1594	0.1591	0.0003	0.1564	0.0003	0.9981	0.9810	1.0172
				0.4193				0.9893		1.0030
4	130	46	0.4238	0.4257	0.0005	0.4178	0.0004	1.0044	0.9860	1.0189
				0.3667				0.9942		1.0120
5	240	22	0.3688	0.3723	0 0003	0.3624	0.0003	1.0094	0.9826	1.0273
				0.2290				0.9914		1.0144
6	250	20	0.2310	0.2325	0.0001	0.2258	0.0003	1.0065	0.9773	1.0297
				0.3911				0.9974		1.0091
7	200	30	0.3922	0.3971	0.0000	0.3876	0.0002	1.0126	0.9884	1.0245
				0.3919				0.9872		1.0061
8	75	70	0.3970	0.3979	0.0003	0.3896	....	1.0023	0.9813	1.0214
					(Series II—40cc HNO_3 per L)					
9	140	46	0.4473	0.4490	0.0005	0.4367	0.0000	1.0038	0.9763	1.0282
10	145	30	0.2879	0.2776	0.0000	0.2764	0.0013	0.9642	0.9600	1.0043
11	130	40	0.2445	0.2408	0.0003	0.2382	0.0012	0.9849	0.9742	1.0105
12	85	40	0.2308	0.2347	0.0013	0.2291	0.0012	1.0169	0.9928	1.0244
					(Series III—80cc HNO_3 per L)					
13	105	60	0.4346	0.4287	0.0001	0.4244	0.0020	0.9864	0.9719	1.0101
14	....	....	0.5377	....	....	0.5202	0.0030	....	0.9674	....
15	130	65	0.5385	0.5257	0.0050	0.5142	0.0045	0.9762	0.9349	1.0223
16	75	60	0.3232	0.3171	0.0025	0.3232	....	0.9811	1.0000	0.9811

the errors resulting from drying the peroxide at a temperature too low to expel all the water, and from the oxidation of the amalgam during washing and drying. The former values are then too high and the latter too low, thus increasing the ratio of the former to the latter. No nitric acid was used in these determinations.

Table I does not include the deposits of copper in the coulometer. It will be noted in these earlier results that the ratios of the deposit of lead at the anode to that at the cathode are distinctly higher and more variable than is the case with the new results for Series I shown in Table II.

Discussion of Results. As shown in Table II, the results for solutions containing free nitric acid are so variable for the different experiments and so inconsistent for the two cells in each experiment, that one seems justified only to conclude the action of some variable and uncontrolled factor. However, even from these acid solutions, the deposits of lead at both the anode and cathode are approximately equivalent to the corresponding deposit of silver, and also, for a distinct change in concentration of nitric acid, there is not any marked change in the ratio of the amount of lead deposited at the anode to that deposited at the cathode.

For the experiments in which no nitric acid was added to the solution of lead nitrate, the results are distinctly less variable, both for the separate experiments and for the two cells in each experiment. Using some variation in the amperage for the different experiments, and with a considerable difference in the time each ran, there is a fair constancy in the ratios for each of the two deposits of lead to the silver in the coulometer, and, consequently, for the one deposit to the other; and also there is a fairly satisfactory agreement in the amount of the deposits in the two cells. It will be noted that, with one exception, the amount of lead found in the anodic deposit was always more than the lead equivalent of the silver, and that in the cathodic deposit was always less.

Apparently, then, for the solutions made up by dissolving lead nitrate in water, one must conclude either that there is not deposited (under the conditions maintained in this work) at the cathode or at the anode an amount of lead equivalent to the amount of silver, the former being less and the latter greater; or that some error in the manipulation of the apparatus or in the methods of analysis has prevented the recognition of the deposit of an electrochemical equivalent of lead at either of the electrodes.

The average of the ratios of the lead deposited at the anode to the lead equivalent of the silver is 1.0053 for the eight experiments; and for the cathodic ratio the average is 0.9864. These averages indicate the deposition at the anode of an amount of lead 0.5 per cent more, and at the cathode 1.4 per cent less, than the electrochemical equivalent of the silver. The variation of the individual ratios from these averages is approximately 0.5 per cent.

In considering the explanation of the cause of these variable results, one comes first to the question of the accuracy of the coulometer. Many careful researches have resulted in the adoption of the porous

cup type of silver coulometer as the standard for the measurement of electrical current. As already mentioned, the manipulation of the coulometer in the present work would not give the high degree of accuracy attained by Richards and Anderegg, but it seems probable that the error involved in these measurements is small.

The second source of error to be considered is in the analytical methods used for the determination of the lead. In the handling of the peroxide the chief difficulty has been in drying the deposit under conditions that will remove all the water and yet not convert any of the peroxide to monoxide. This determination has been worked over many times and Smith finally recommends drying at a temperature of at least 200° C., when the error involved is stated to be small. The drying in this work was made from 230° to 300° C. No appearance of the yellow monoxide was noted; if there had been some undetected, the results calculated would be lower than otherwise, owing to the fact that the deposit would weigh less than if there were no such conversion. In one set the values for the peroxide were checked by conversion to the monoxide and weighing as such. Although it may be possible that the combined errors of the coulometer and the general manipulation could account for the difference between the lead at the anode and the lead equivalent of the silver, it does not seem probable.

If one uses the empirical factor 0.853 of Hollard[1] for lead in lead peroxide instead of the theoretical value of 0.866 in calculating the results for Table II, a considerable difference is noted in the relationships involved. These values have been inserted in the table in the parentheses. It will be noted that the ratio of the lead deposited at the anode to the lead equivalent of the silver falls in all the cases considered to values much closer those for the ratio of the lead deposited at the cathode to the lead equivalent of the silver. In some cases they are very close together. The average of these anodic ratios becomes 0.990 as compared with 0.986 for the cathodic ratios. These values indicate the deposition of an amount of lead at each electrode slightly less than the electrochemical equivalent of the silver deposit.

For the determination of the lead in the amalgam the data presented by the authors in the preceding paper indicates that the method employed is accurate. These results showed that the weight of lead not recovered by this procedure was less than 0.1 per cent of that originally added to the mercury. The error in this determination would not seem to account for the variation of 1.4 per cent between the lead found and the lead equivalent of the silver.

PART III—SUMMARY.

In this work involving the electro-deposition of lead from aqueous solutions of the nitrate, there has been presented:

1. A review of the investigations bearing upon the division of lead between the two electrodes during the electrolysis.

2. Data associated with the quantitative relationship between the anodic and cathodic deposits of lead, and the relationship between these and the deposit of silver in a coulometer.

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[1] Ibbotson and Aitchison—Analysis of Non-Ferrous Alloys, p. 60 (1915).

SOME EXPERIMENTS ON THE DETERMINATION OF LEAD IN LEAD AMALGAM.

M. G. MELLON and H. F. REINHARD.

In working with lead amalgams several types of procedure have been employed by various individuals for obtaining the concentration of the lead in the amalgams. These methods may be conveniently classified as electrolytic, gravimetric, and physico-chemical. There follows a brief outline of the principles involved in the three types of procedure.

Electrolytic Methods. One electrolytic method takes advantage of the scheme used for preparing the amalgam. Under certain conditions Stähler and Alders[1] found that lead deposits in a mercury cathode. They maintain that the amalgam formed may be washed with water, alcohol, and ether, and weighed. Knowing the original weight of the mercury serving as the cathode, the increase in weight represents the amount of lead deposited. From these two weights the concentration of the lead may be calculated. In using this procedure Vortmann[2] encountered difficulties from the oxidation of the amalgam when the electrolyte was alkaline. The authors have had similar trouble when working with lead amalgams in which the lead was deposited from aqueous solutions of lead nitrate. The above procedure is ultimately a method of preparing an amalgam in which the concentration of the element deposited in the mercury is known, rather than a method of analysis.

A somewhat similar method has been employed by Richards and Wilson[3] for amalgams of thallium, indium and tin. As in the above method, the amalgams were prepared by depositing the different elements electrolytically in a mercury cathode. The concentration of the metal deposited was obtained by means of a silver coulometer included in the electrical circuit during the electrolysis, the assumption being that the element deposited in the mercury was equivalent in amount to the silver deposited in the coulometer. The percentage composition of the amalgam could then be calculated from the weights of silver and of the mercury serving as cathode.

A third electrolytic method is that suggested by Smith.[4] It involves the solution of the amalgam in nitric acid and the deposition of both elements. With properly arranged apparatus, and under suitable conditions, the lead deposits at the anode as the peroxide and the mercury at the cathode.

Gravimetric Methods. The methods outlined here for the gravimetric estimation of the concentration of lead in lead amalgams involve

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[1] Ber. 42, 2685 (1909).
[2] Ibid. 22, 2756 (1891).
[3] Carnegie Inst. Pub. 118, 1 (1909).
[4] Electro-Analysis, p. 229 (1918).
Smith and Moyer—J. Anal. Ch. 7, 252 (1893); Z. anorg. Ch. 4, 267 (1893).
Smith and Heidenreich—Ber. 29, 1585 (1896); Z. Elektrochem. 3, 151 (1897).

the solution of the amalgam and the subsequent separation of the two elements by the precipitation of one of them. The first of these is based upon the fact that mercuric sulfide is insoluble in dilute, boiling nitric acid (Sp. G. 1.2-1.3), while lead sulfide is soluble. For this determination Treadwell,[1] and also Scott,[2] recommended the precipitation of the elements from their solution (the mercury being present entirely in the mercuric form) by hydrogen sulfide. The precipitate is filtered off, washed with hydrogen sulfide water, transferred to a dish and boiled for a considerable time with the dilute nitric acid. The solution is then diluted, the mercuric sulfide filtered off and washed with water containing nitric acid. Certain precautions are necessary in the final determination of the two elements.

As a second gravimetric method Crookes[3] suggests the addition of sulfuric acid to the solution containing the lead and mercury, followed with alcohol to form about one-sixth the volume of the solution. The precipitated lead sulfate requires washing with dilute alcohol containing a little sulfuric acid. The separation of the lead by this means is based upon the insolubility of its sulfate and the solubility of the mercuric sulfate. Horsford used this method.[4]

Physico-Chemical Methods. Richards and Wilson[5] have measured the densities of lead amalgams as a means for obtaining the concentration of the lead. From these results they were then able to obtain this concentration by reference to a curve showing the variation in density of the amalgam with change in the amount of lead present. Such a method is based upon the fact that the physical property being measured varies with, or is a function of, the concentration of the constituent being determined.

Meyer[6] and Richards and Forbes[7] have investigated a second, interesting physico-chemical method. Their work included the elements zinc, cadmium, lead, tin, copper, and sodium. The principle of the method has as its basis the familiar equation for electrode potentials as developed by Nernst. When applied to concentration cells in which the two electrodes are amalgams or alloys it has the form—

$$E = \frac{RT}{nF} \ln \frac{c_1}{c_2}$$

in which the various terms all have their usual significance. In such a combination as

$$Zn.Hg\ (C_1)—ZnSO_4\ (Sat.\ Sol.)—Zn.Hg\ (C_2)$$

one will find a given potential whose magnitude will depend upon the concentrations of the two amalgams and the temperature, as the chief factors. To apply the above equation in calculating the concentration of a given element in an amalgam, one would set up a combination such as that mentioned for zinc amalgams, using an amalgam of accurately

[1] Treadwell-Hall—Analytical Chemistry II, p. 194 (1915).
[2] Standard Methods of Chemical Analysis, p. 271 (1917).
[3] Select Methods in Analytical Chemistry, p. 324 (1894).
[4] Am. J. Sci. [2] 13, 305 (1852).
[5] Carnegie Inst. Pub. 118, 1 (1909).
[6] Z. phys. Ch. 7, 477 (1891).
[7] Carnegie Inst. Pub. 56, 1 (1906).

known concentration for one of the electrodes and the one of unknown concentration for the other. The potential E could then be measured for the combination. This leaves as the one unknown quantity in the equation the concentration of the amalgam being measured, and its value may readily be calculated.

Hulett and Minchin[1] have made use of this scheme in their study on the distillation of amalgams and the purification of mercury. They state that one part of zinc can be detected with certainty in ten billion parts of mercury, and that the method is probably the most delicate analytical procedure known.

Criticism of Methods. None of the preceding methods seemed to meet the requirements, as to ease and accuracy, for certain work that is being conducted in this laboratory. As already noted, the first electrolytic method was unsuitable because of oxidation of the amalgam during washing and drying.

For the method involving the electrolytic separation of the lead and mercury, or the gravimetric separation, either of the mercury as mercuric sulfide, or of the lead as lead sulfate, the amalgams under investigation contained entirely too much mercury. There was generally present from 30 to 50 grams of this element and only about 0.5 gram as the maximum amount of lead. For an electrolytic separation this amount of mercury would require altogether too much time, even if there were involved no other undesirable features. Likewise, in the gravimetric methods which involve a separation by precipitating one of the constituents, the mechanical difficulties of handling a solution containing such a large proportion of mercury would be too great to insure a high degree of accuracy in the determinations.

Two distinct difficulties are evident in the method involving the determination of the density of the amalgams. In the first place, it is not easy to handle lead amalgams without oxidation of the surface. The difficulty is increased if the amalgam is wet and must be dried during the procedure. In the second place, the densities of lead and mercury are so near each other that a considerable change in density of the amalgam does not result from a small change in the concentration of the lead in the amalgam. This means that the accuracy in determining the concentration of the lead by this method would not be so great as in the case of such elements as cadmium and zinc, whose densities are much less than that of lead.

Although the method based upon the measurement of the potentials of amalgams apparently may be very accurate, distinct precautions must be observed in making such determinations. Rather elaborate electrical apparatus is required along with an accurately controlled thermostat for holding the temperature factor constant. No attempt was made to use the method in the present work, although it is hoped a later study may be made on concentration cells with lead amalgams. Previous[2] work has indicated that, under certain conditions, a very constant and reproducible potential is obtained for a saturated lead amalgam.

[1] Phys. Rev. 21, 388 (1905).

[2] Mellon and Henderson—J. Am. Chem. Soc. 42, 676 (1920).

Present Work.

Oxidation of Lead Amalgams. As already stated, in the course of some work in this laboratory with lead amalgams, it was not found possible to handle them according to the method of Stähler and Alders without having marked evidence of oxidation, even with only a few hundredths of a gram of lead present. Amalgams prepared electrolytically were always bright, and remained so during washing with water and alcohol. When washed with ether, however, there often formed on the surface of the amalgam a dark film which was easily lost on further washing. If washed immediately and quickly with the ether, not much of the film formed; but the longer the time of washing, the more film there was present. It was difficult to avoid losing it when washing by decantation; and if much was present, some was always lost. On standing any length of time following the washings with just water and alcohol, there was always considerable oxidation.

To show this oxidation of the amalgam on standing, and the resulting loss in weight with washing, the following determinations are typical, except that the errors are considerably exaggerated due to the length of time the amalgams stood before washing. These amalgams were made up by dissolving a known weight of lead in a known weight of mercury and allowed to stand in a beaker 48 hours. After washing with the liquids mentioned, the amalgams were dried in a desiccator and reweighed, with the results shown in Table I. Numbers 1 and 2 were washed once with 10 cc. of water and twice with 10 cc. portions of alcohol, while numbers 3 and 4 had, in addition to this, two washings with ether.

Table I.

Loss in Weight of Amalgams During Washing.

No.	Weight of Mercury	Weight of Lead	Loss
1	43.0182	0.8496	0.0138
2	40 8870	1.0832	0.0076
3	57 2745	1.0357	0.0162
4	39.2819	0.8600	0.0227

Development of Method of Analysis. On account of the defects inherent in the methods already outlined for the analysis of lead amalgams, it seemed desirable to have available a method for determining the concentration of the lead involving some procedure by which the element could be brought easily from the amalgam into aqueous solution, and then determined gravimetrically in this solution. A solution of copper nitrate was selected as a promising possibility for obtaining the replacement of the lead in the amalgam by another element, thus bringing it into aqueous solution from which it could be precipitated. Copper sulfate was rejected because it brought about the formation of lead sulfate very shortly, which seemed to retard the replacement process. The procedure adopted consisted in covering the amalgam in a beaker with 25 cc. of a 10 per cent solution of copper nitrate for a period of 15 to 24 hours, decanting the solution, and washing the remaining amalgam. Copper is less soluble in mercury than lead, and

many of the determinations showed considerable brownish-red material on the surface of the amalgam, after standing in contact with the solution of copper nitrate for several hours. This was found to be largely copper, along with some mercury, and the solution was always filtered from this precipitated material.

Determination of Lead in the Amalgam as Lead Sulfate. In trying out the method for displacing the lead from the amalgam by means of a solution of copper nitrate, the first attempt to precipitate the lead was with sulfuric acid. Amalgams containing known weights of lead stood four days in contact with 40 cc. of a 10 per cent solution of the copper nitrate. After decanting the resulting solution, an additional 10 cc. portion of the copper nitrate stood on the amalgams for 30 minutes. From the total, warm solution the lead was precipitated with dilute sulfuric acid. The weight of lead sulfate was determined by filtering it on a Gooch crucible, the ignition being accomplished by supporting the crucible in an asbestos ring placed in a larger crucible and heating the latter to dull redness for 15 minutes. The weight of lead was found to be uniformly low, as shown in Table II.

TABLE II.

Determination of Lead in Lead Amalgam as Lead Sulfate.

No.	Lead Taken	Lead Found	Percent Loss
1	0.5650	0.5606	0.78
2	0.4748	0.4704	0.92
3	0.5108	0.5058	0.98
4	0.5024	0.4977	0.93

Solubility of Lead Sulfate in a Solution of Copper Nitrate. Assuming that the low values for the lead found resulted from the solubility of the lead sulfate in the solution of copper nitrate, definite weights of prepared lead sulfate were allowed to stand four days in a 10 per cent solution of the copper nitrate. The precipitate was then filtered off and weighed as before. The results shown in Table III are only preliminary and more accurate determinations will be made under varying conditions, but the increase in solubility with increase in concentration of copper nitrate is evident.

TABLE III.

Solubility of Lead Sulfate in a Solution of Copper Nitrate

No.	Vol. of Sol. of $Cu(NO_3)_2$	$PbSO_4$ Taken	$PbSO_4$ Found	Percent Loss
1	25cc	0.7000	0.6764	3.39
2	50	0.7000	0.6556	6.33
3	50	0.7000	0.6533	6.61

Solubility of Lead Chromate in a Solution of Copper Nitrate. The foregoing work on the determination of the lead as lead sulfate and on its solubility in solutions of copper nitrate indicated that the results might be due to a failure of the lead to change entirely from a

metallic solution as amalgam to aqueous solution as lead nitrate, that is, a state of equilibrium was established, leaving part of the lead still in the amalgam from which it did not precipitate as the sulfate; or it might be due to the solubility of the lead sulfate in the excess of copper nitrate, or to a combination of the two. The method seemed to be useless for quantitative determinations and no further work was attempted with it.

With the idea that lead might be precipitated quantitatively as the chromate in the presence of copper nitrate, the solution of lead nitrate being used as electrolyte was analyzed for its concentration of lead by precipitating the metal, in the presence of a few drops of acetic acid, with potassium dichromate.[1] The precipitate was dried at 120° C. in a Gooch crucible. Then the same volume of solution of lead nitrate was treated as before except for the addition of 20 cc. of the solution of copper nitrate before the precipitation of the lead chromate. The results shown in Table IV indicate either that the solubility of lead chromate in a solution of copper nitrate is very small, or that errors are inherent in the procedure which serve to compensate such solubility.

TABLE IV.

Solubility of Lead Chromate in a Solution of Copper Nitrate

No.	Volume of Solution of Copper Nitrate	Volume of Solution of Lead Nitrate	Weight of $PbCrO_4$
1	None	50cc	0.3316
2	"	"	0.3313
3	20cc	"	0.3312
4	"	"	0.3309
5	"	"	0.3308

Determination of Lead in Lead Amalgam as Lead Chromate. Since there seemed to be only a small amount of lead lost when precipitated as the chromate, in the presence of 20 cc. of a 10 per cent solution of copper nitrate, the next step was to ascertain whether the lead in a lead amalgam could be quantitatively determined as the chromate. Following the procedure used in the attempt to determine the lead as sulfate up to the point of precipitating the lead, a few drops of acetic acid was then added, followed by a solution of potassium dichromate sufficient to complete the precipitation. The amalgam had been made

TABLE V.

Determination of Lead in Lead Amalgam as Lead Chromate

No.	Lead Taken	Lead Found	Difference	Percent Variation
1	0.3153	0.3149	—0.0004	—0.12
2	0.2616	0.2615	—0.0001	—0.04
3	0.2763	0.2761	—0.0002	—0.07
4	0.3013	0.3014	+0.0001	+0.03
5	0.2751	0.2754	+0.0003	+0.11

[1] Scott—Standard Methods of Chemical Analysis, p. 236 (1917).

by adding a known weight of lead to 40 to 50 grams of mercury and allowing it to dissolve in the mercury before the addition of the solution of copper nitrate. The results shown in Table V indicate that the method is satisfactory for a quantitative determination of the lead in a lead amalgam.

Summary.

The material presented in this paper includes:

1. A brief review of some of the methods that have been proposed for determining the concentration of lead in lead amalgams, together with a consideration of the possibility of applying them to the analysis of such amalgams containing a large amount of mercury and a relatively small amount of lead.

2. An account of some experiments made with the object of developing a more desirable procedure for the above determination. This work has involved the following determinations:

   a. The loss in weight of lead amalgams during washing.

   b. The amount of lead in lead amalgams by weighing the metal as the sulfate and as the chromate.

   c. The solubility of lead sulfate and of lead chromate in an aqueous solution of copper nitrate.

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Chlorination of Mixed Silver Halides in Gooch Crucibles.

M. G. Mellon and J. C. Siegesmund.

Any two of the three halogens, chlorine, bromine, and iodine, in the form of their salts, may be determined in a mixture of these salts by the familiar indirect, gravimetric method. This procedure consists of the following steps: precipitating the two halogens together in the form of their silver salts; drying and weighing as such in a Gooch crucible; chlorinating the weighed residue in order to replace the bromine or iodine, or both, and thus converting this residue to silver chloride; and the weighing of the latter salt. Then from the weights of sample, mixed silver halides, and the resulting silver chloride, it is possible to calculate the percentage of the halogens in the sample.

As an example of an indirect analysis, the determination of one pair of the three halogens is included in the course on general quantitative chemical analysis as given in this laboratory. The scheme employed[1] for the chlorination of the mixed silver halides has been to transfer the weighed residue, along with the asbestos in the Gooch crucible, to a boat. The boat was then placed in a hard glass tube, where it could be heated with a burner when necessary, and chlorine passed through the tube until a constant weight was obtained, indicating a complete conversion to silver chloride. This procedure necessitates at least four weighings: the sample, the mixed silver halides, the boat and contents before chlorination, and the same after chlorination.

One distinct liability for error in the process just described lies in the transfer of the asbestos and mixed silver halides from the Gooch crucible to the boat. It is often a difficult matter to obtain a quantitative transfer of the halides, especially when a film clings to the inside surface of the crucible. Small pieces of asbestos in the holes in the crucible may be neglected, since it is necessary to transfer only those portions upon which are liable to be found the particles of silver halide.

With the aim of avoiding the troublesome transfer of the contents of the crucible to the boat, the above procedure has been modified so as to chlorinate the mixed halides directly in the crucible. The scheme adopted for class work consists in placing the Gooch crucible inside a larger crucible, covering the latter with a watch glass having a hole in the center and with the convex side up, and bringing chlorine in contact with the residue by means of a glass tube extending down through the hole in the watch glass to within about 1 cm. of the bottom of the crucible. To hasten the chlorination the outer crucible may be heated. The bromine or iodine replaced are easily driven out of the inside crucible. They often condense at first on the under side of the watch glass but soon disappear with later heating of the crucibles. It is sometimes well to break up a hard residue by means of a glass rod before chlorination, since it is not as well exposed to the action of the chlorine as when spread out in a boat. The weighings neces-

[1] Mahin—Quantitative Analysis, p. 115 (1919).

sary with this procedure include the sample, the mixed halides, and the remaining silver chloride, one less than with the other procedure.

The modified method is essentially similar to that employed by Treadwell[1] who filters the mixed halides into a weighed Fresenius asbestos filter tube of difficulty fusible glass. The tube and contents are weighed, the halides chlorinated in it, and the tube again weighed.

The results shown in the accompanying table illustrate typical determinations as made using the two schemes of chlorination.

Sample Number	Chlorination in Boat		Chlorination in Crucible	
	%Cl	%Br	%Cl	%Br
1	35.30	27.80	35.58	27.51
	35.29	27.81	35.44	27.57
	35.27	27.56	35.53	27.45
	35.13	27.92	35.42	27.60
2	38.10	24.90	37.90	25.10
	37.82	25.18	38.07	24.80
	37.74	25.14	38.17	24.76
	38.03	25.01	38.10	24.74
			38.10	24.78
			37.96	25.20
	%Cl	%I	%Cl	%I
3	45.63	18.75	45.59	18.91
	45.50	19.07	45.44	18.79
	45.62	18.97	45.50	18.88
	45.70	18.90		
4	50.41	12.46	50.20	12.92
	50.33	12.55	50.35	12.72
	50.30	12.63	50.26	12.60
5	52.95	9.71	53.15	9.35
	53.05	9.70	53.17	9.45
	53.08	9.50	53.10	9.50
	52.99	9.60		
	%Br	%I	%Br	%I
6	17.01	19.78	17.02	19.74
	16.91	19.36	16.97	19.68
			17.19	19.39

The analyses for sample No. 1 were made by the junior author. The other results have been taken from the reports submitted during 1919 and 1920 by the students in general quantitative chemical analysis. While these analyses do not check as well as might be desired, most indirect, gravimetric methods are subject to rather large errors unless approximately equal amounts of the two constituents are present and the multiplying factors used for the calculation is small. Ashley[2] cites an example where an error of 1 mg in a weighing results in a percentage error of 26.20 for one of the constituents.

Conclusion.

A modification of the method for chlorinating mixed silver halides has been proposed. Its advantage over the method previously employed

[1] Treadwell-Hall—Analytical Chemistry, Vol. II, p. 334 (1915).

[2] Chemical Calculations, p. 190 (1913).

lies in the saving of one weighing, and in avoiding the liability of loss in transferring the asbestos and mixed halides from a Gooch crucible to a boat.

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ACYL DERIVATIVES OF O-AMINOPHENOL.

R. E. NELSON AND H. L. DAVIS.

When o-aminophenol, ($HOC_6H_4NH_2$), is acylated with two different acyl groups, one group attaches itself to the nitrogen and the other to the oxygen, forming a stable diacyl compound. In attempting to prepare the isomer of the above compound, the isomer rearranges spontaneously forming the same diacyl compound. A molecular rearrangement takes place and the group finally found attached to the nitrogen depends on the two acyl groups used.

Saponification of the diacyl compound removes the acyl group attached to the oxygen first.

If the remaining hydrogen of the acylated amino group be replaced by an alkyl group no rearrangement takes place.

A typical example of this rearrangement is found in Ransom's[1] work. He acylated oxyphenylurethane, ($HOC_6H_4NHCO_2C_2H_5$), with benzoyl chloride in alkaline solution. The attempt to prepare the isomer of benzoyloxyphenylurethane, ($C_6H_5CO.OC_6H_4NHCO_2C_2H_5$), by acylating benzoyl-o-aminophenol, ($HOC_6H_4NHCOC_6H_5$), with ethyl chlorformate in alkaline solution, resulted in the formation of benzoyloxyphenylurethane, the carbethoxy group,—$CO_2C_2H_5$, occupying the position formerly held by the benzoyl group.

Ransom and Nelson[2] observed similar rearrangement in attempting to prepare the isomer of carbamyl o-oxyphenylethylurethane, ($C_5H_{11}CO_2.OC_6H_4NHCO_2C_2H_5$).

If an acyl group is attached to the oxygen of o-nitrophenol and the acylated nitrophenol is reduced the resulting free base rearranges. The acyl group exchanges position with one hydrogen of the amino group.

Stieglitz and Upson[3] investigated the time of arrangement of a number of substituted monoacyl derivatives of o-aminophenol, substituting chlorine, bromine and the methyl group about the ring, and concluded that, "the more or less positive character of the amino group, as shown by the affinity constants, does not seem to have any paramount influence in determining the tendency of the base to undergo rearrangement, as measured by the rate of rearrangement", but that, "the velocity constant depends more on changes affecting the neighboring carbalkoxyl groups".

Raiford[4] did not find the rearrangement of diacyl derivatives affected by the substitution of negative groups about the ring.

From the previous work done it seems that the diacyl derivatives of o-aminophenol tend to undergo rearrangement regardless of the

[1] Amer. Chem. Journ. Vol. 23, No. 1, 1.
[2] Jour. Amer. Chem. Soc. Vol. 36, N 2, 390.
[3] Amer. Chem. Journ. Vol. 31, No. 1, 497.
[4] Journ. Amer. Chem. Soc. Vol. 41, No. 12, 2068.

weight of the two acyl groups concerned, or whether the latter possess carbonyl or carboxyl groups. Neither does the substitution of negative groups about the benzene nucleus affect the tendency to rearrange.

The purpose of this investigation has been principally (1), to determine whether closely related alkyl radicals in the aliphatic acyl groups affected the rearrangement, and (2) to determine whether the same alkyl radical in the different acyl groups affected the rearrangement.

Experimental Part.

Acetyloxyphenylurethane, ($CH_3CO.OC_6H_4NHCO_2C_2H_5$), was prepared from oxyphenylurethane and acetic anhydride in alkaline solution. White needle-like crystals melting at 72.9° to 73.4° were obtained from ligroin. On saponification oxyphenylurethane was obtained, showing the carbethoxy group to be attached to the nitrogen in acetyloxyphenylurethane.

Action of Ethylchloformate on o-Acetylaminophenol.

When o-acetylaminophenol, ($HOC_6H_4NHCOCH_3$), is treated with ethylchlorformate in alkaline solution acetyloxyphenylurethane, and not its isomer, is obtained. The product of saponification is oxyphenylurethane, showing the carbethoxy group attached to the nitrogen where the acetyl group had been.

In connection with the behavior of the acetyl group, Raiford's work with unsubstituted o-aminophenol was repeated and the exchange of position between the acetyl and benzoyl groups observed.

Propionyloxyphenylurethane, ($C_2H_5CO.OC_6H_4NHCO_2C_2H_5$), was prepared from oxyphenylurethane and propionic anhydride in alkaline solution. Crystals of long, white, silken needles melting at 41.7° to 42.4° were obtained from dilute alcohol. Saponification showed the carbethoxy group to be attached to the nitrogen.

Propionl-o-aminophenol, ($HOC_6H_4NHCOC_2H_5$), was prepared from o-aminophenol and propionyl chloride in ether solution. Small white, cubical crystals melting at 76.2° to 77.2° were obtained from ligroin slightly diluted with ether.

Action of Ethylchlorformate on Propionyl-o-aminophenol.

On treating propionyl-o-aminophenol, in alkaline solution, with ethylchlorformate a diacyl compound is formed identical with, and in fact is, propionyloxyphenylurethane. Saponification yields oxyphenylurethane, showing that the carbethoxy and the propionyl groups had exchanged places.

When two closely related alkyl radicals, one being attached to the carbonyl group and the other to a carboxy group, are used in the preparation of a diacyl derivative of o-aminophenol, the acyl group containing the carboxy group is always found attached to the nitrogen. When necessary a molecular rearrangement takes place to effect this.

When the same alkyl radical is used, in one case attached to a carbonyl group and in the other to a carboxy group, the acyl group containing the carboxy group, again, is found attached to the nitrogen.

Purdue University.

A Subterranean Cut-Off and Other Subterranean Phenomena Along Indian Creek, Lawrence County, Indiana.

Clyde A. Malott.

The drainage basin of Indian Creek in Monroe, Greene, Lawrence, and Martin counties, Indiana, offers a number of interesting physiographic phenomena. Indian Creek from its source in western Monroe County southwest of Bloomington to its entrance into East White River a few miles above Shoals in Martin County, traverses a sinuous route some 50 to 75 miles in length, though the direct distance is but little more than 25 miles. The valley in the upper portion is rather broad and lies on a limestone plain which is perched from 100 to 150 feet above the more deeply intrenched streams on either side of the basin. This condition of its upper portion has resulted in wholesale subterranean piracy, and some 15 square miles in area have been diverted from the surface route through Indian Creek to the more deeply intrenched streams on either side.[1] In the middle and lower portions of Indian Creek basin the valley is very tortuous and narrow. It is deeply set in a dissected plain, the narrow valley floor lying from 200 to 300 feet below the preserved portions of the dissected plain. The upper parts of the valley sides are composed of clastic rocks belonging to the Chester series. These rocks often form benches with abrupt sides of massive sandstone facing the valley. The lower parts of the valley sides are composed of the so-called Mitchell limestone which is exposed in the steep, wall-like sides of the meander curves. Within the meander curves of the valley occur local sinkhole plains far below the dissected surface of the plain in which the valley is cut. Springs of considerable size enter the stream and furnish a large part of the perennial waters. Some of these springs are mineral springs, such as at Trinity Springs in Martin County. At one place a complex meander curve more than 3 miles in length is in the process of being cut off through the development of subterranean drainage beneath the spur of upland across the narrow neck of the meander loop. It is with this feature that the present paper chiefly deals.

The accompanying topographic sketch, Fig. 1, shows a small area of 4 square miles in western Lawrence County through which Indian Creek passes in a very sinuous route. The area lies in T. 5 N., R. 2 W. The village of Silverville lies a mile south of the area, and Armstrong station on the Bedford-Switz City Branch of the Monon Railway is about 1 mile north of the area. The area is about 9 miles west of Bedford. This locality has been mapped in particular to show the developing subterranean cut-off in Indian Creek. The locality also is

[1] See the Bloomington, Indiana, Quadrangle. Also see, Beede, J. W., "The Cycle of Subterranean Drainage as Illustrated in the Bloomington, Indiana, Quadrangle," Proc. Ind. Acad. Sci. for 1910, pp. 107-111.

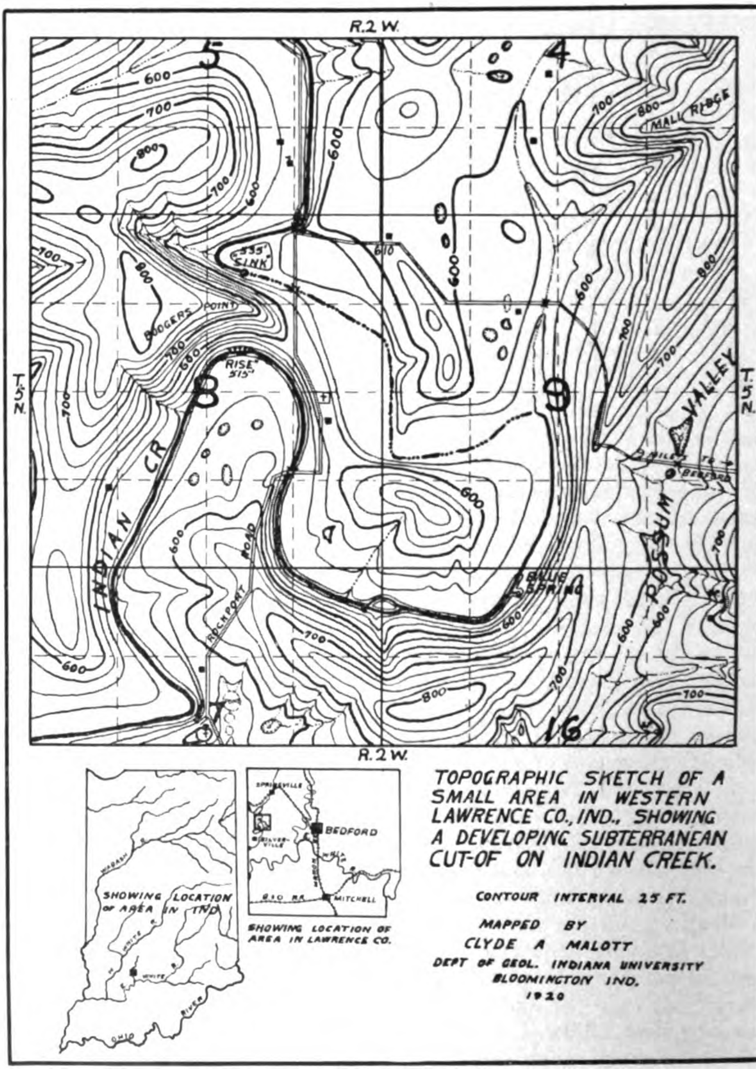


FIG. 1.

interesting from the standpoint of other features present, and these will be briefly discussed.

Indian Creek in this locality lies in a very sinuous valley and is deeply sunk below the higher upland divides. The length of the stream across the two miles of the mapped area is 5¾ miles, or nearly three times the direct distance. The stream both above and below the mapped area is but slightly less sinuous. It occupies a narrow valley which is rarely more than 200 yards in width at the bottom. It is usually at one side or the other of the narrow valley floor and at the foot of a

bluff or steep rocky slope, varying from 30 to 275 feet in height. (See Fig. 5.) The most striking feature of the stream and its valley is the complex eastwardly turned meander. This meander is more than 3 miles in circuit and returns to within one-fourth mile of the place where it begins. (See Fig. 1.)

The topographic condition of the area is that of an irregularly dissected plain somewhat beyond the stage of maturity. The land forms present are far from being uniform in kind and size. Diversity rather than uniformity of land forms persist throughout the region. Prominent ridges are present, but their crests are individually uneven and rough. Rock benches frequently occur on the higher flanks of the valley sides, but are not always present there. Great sags and prominent eminences occur. The ravines are sharp and rocky, and their upper parts possess very steep descents. Local isolated sinkhole plains are present midway between the streams and the rough ridge crests. These local sinkhole plains are chiefly associated with the valleys of tributary streams in their approach to the main valley. Some of the sinkholes have become plugged and have become small lake basins. The larger topographic features and their relationships are shown on the accompanying topographic sketch, Fig. 1.

The altitudes within the area of the sketch map range between 510 and 875 feet above sea level. The maximum relief is 365 feet. The immediate relief is as much as 275 or 300 feet. The chief relief forms are the great bluffs on the outside of the meander turns, the sharp uneven sandstone ridges, and the isolated hill within the big meander loop. The curved bluffs on the outside of the meander turns are dis-

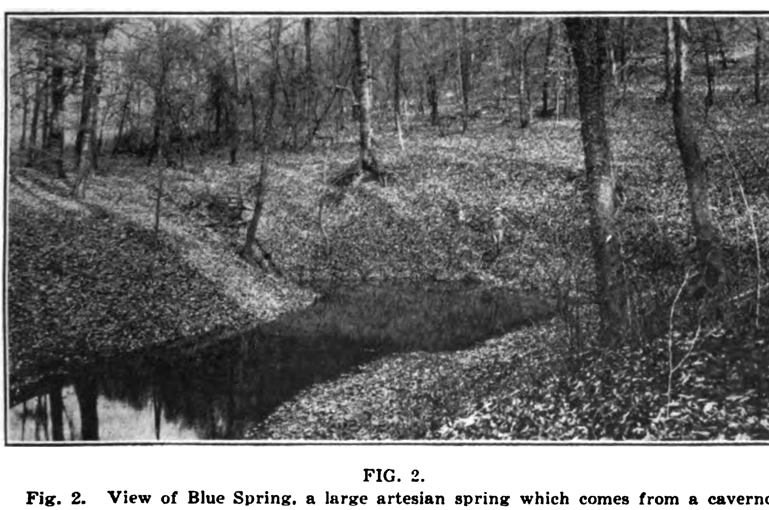


FIG. 2.

Fig. 2. View of Blue Spring, a large artesian spring which comes from a cavernous opening at the foot of the hillside adjacent to Indian Creek. The waters which have their exit here have been drained from Possum Valley which lies east of Indian Creek, and have been diverted from their former surface course through the development of subterranean channels. The region furnishes an excellent example of subterranean stream piracy.

continuous and alternate from side to side of the valley. These relief forms are in great contrast to the local sinkhole plains developed some 50 to 100 feet above the valley floor of Indian Creek.

The ridges of the area are composed chiefly of massive sandstones, though their lower and more gentle slopes are composed of the upper part of the Mitchell limestone. The sinkhole plains are developed approximately 100 feet below the top of the Mitchell limestone, or near the top of the St. Louis geologic unit. The local sinkhole areas as shown in sections 8 and 17 are somewhat lower than those in sections 4 and 9. This is in harmony with the dip of the strata to the southwest.

Features accompanying subterranean drainage are very much in evidence. Possum Valley, a small portion of which is shown on the topographic sketch, is a streamless valley which lies east of Indian Creek valley. This valley offers some interesting physiographic phenomena. As a valley basin it is some 3 or 4 miles in length. It is rimmed by sandstone ridges with the exception of the opening on the south. Its floor is occupied by numerous sinkholes and swallow-holes. Small streams descend from the sandstone ridges and hills and enter the swallow-holes in the bottom of the valley. Some of the ravines or small streams are headed by springs which commonly issue from the foot of steep sandstone bluffs near the tops of the ridges. Two such springs are shown on the topographic sketch. South of the area covered by the topographic sketch the valley is open and is occupied by a normal surface stream, Hackley Creek, which enters Indian Creek a mile or so below. Little or none of the waters which drain into the swallow-holes enter Hackley Creek. These waters apparently enter Indian Creek

FIG. 3.

Fig. 3. View showing the pool in Indian Creek channel in which the waters sink. During low water condition all the water enters the subterranean channels here and passes southward beneath "Boogers Point", re-entering the surface channel of Indian Creek after passing through a subterranean channel or channels one-fourth mile in length. The fall of the subterranean route is approximately twenty feet. The route taken by the surface stream during higher water stages is 3.1 miles in length. (See Fig. 1.)

through an underground system which has its terminus at Blue Spring. (See Fig. 2.) Blue Spring is a spring of great volume which rises out of a cavernous opening at the foot of the rocky meander curve in section 16, and enters Indian Creek channel. Little of the cavernous opening is visible, as the spring is artesian. After heavy rains the muddy waters rise vigorously and in greatly increased volume. During dry weather the pool at the opening is a deep blue color, and the water rises quietly and flows away at one side practically at the level of Indian Creek.

Possum Valley is characteristic of many valleys of its kind developed in the Mitchell limestone along the western margin of its outcrop. Such valleys are almost invariably tributaries to a larger and more deeply intrenched main stream. They have originated as valley basins through normal surface erosion in the clastic rocks of the Chester series. As the main streams were intrenched through downward erosion, the tribuary valleys were also cut down, but less rapidly than the main streams. When the tributary streams had cut through the clastic rocks to the Mitchell limestone, the main streams were already well intrenched within the Mitchell limestone. The tributary streams were thus somewhat perched above the main streams, and possessed a valley floor of limestone. Subterranean drainage gradually developed in the tributary valleys, especially at some distance from their junction with the main streams. In many cases the waters which enter the subterranean channels through the swallow-holes in the middle and upper portions of the near streamless valleys re-enter the valley at the surface and continue to the main stream as a surface stream. But more frequently the waters have been diverted through subterranean channels directly to the main stream, the waters passing beneath the divide between the main stream and the tributary. Beaver Valley west of Mitchell in southern Lawrence County is an example of semi-streamless in its upper portion, the subterranean waters of which in part come to the surface lower down in the valley basin. Possum Valley illustrates the sort in which the water has been diverted by subterranean piracy.

It should be noted that there is a distinct difference in the manner of stream diversion in subterranean stream diversion as compared to surface stream diversion. In the latter kinds of stream diversion the diverting or pirate stream is the sole aggressor, while the diverted or captured stream is wholly passive. In the case of stream diversion through the development of subterranean drainage, the diverted stream is the chief aggressor and brings about its own diversion. Because of such a fundamental difference in the manner of stream diversion, some question arises in the mind of the writer as to the propriety of calling subterranean stream diversion stream piracy, though the expression stream diversion conveys the full meaning of the action.

Subterranean drainage takes place as a matter of economy of distance. The subterranean routes are always shorter and more direct than the abandoned surface routes. In the case of Possum Valley the economy of distance is obvious. The subterranean route under the dividing ridge is very short as compared to the old surface route below,

Streamless valleys of this sort may have one or more than one underground system, but the old surface stream is broken up into a large number of small surface systems. Each tributary of the former surface stream may become a small surface system to itself, possessing its own particular swallow-hole marking the terminus of the individual surface system.

The topographical sketch, Fig. 1, has been prepared especially to show the conditions attending the development of a subterranean cut-off, wherein a great meander loop is being abandoned on account of the development of a sub-surface route across the neck of the meander. The waters of Indian Creek in low water condition disappear at the foot of the steep slope forming the north side of "Boogers Point" spur. (See Fig. 3.) The waters reappear one-fourth mile south in a series of springs at the side of the surface channel where it has returned from

FIG. 4.

Fig. 4. View showing the place where some of the waters from the subterranean cut-off re-enter Indian Creek channel. The series of springs coming out at and slightly above water level indicate that the subterranean route beneath "Boogers Point" spur is not well concentrated.

the complex eastwardly extending meander loop. (See Figures 4 and 5.) Here again is illustrated economy of distance in subterranean drainage over the surface route. The subterranean route beneath "Boogers Point" spur is approximately one-fourth mile in length, whereas the surface route is more than 3 miles in length. The fall is approximately 20 feet, and is sufficiently great to give rise to considerable mechanical erosion along the subterranean route. Such erosion, however, is greatly lessened through the lack of concentration in the subterranean route, as it appears that the route is a diffuse one. The waters at the "sink" disappear chiefly in one pool, though other pools below the main one show indications of water loss. The waters re-enter the channel as broad streams through the accumulated talus at the foot of the meander bluff. The issuing waters extend along the stream, coming out prac-

tically at stream level, for a distance of 100 yards or more. There is nothing spectacular about either the "sink" or "rise". In high water the surplus passes through the surface channel around the great meander curve.

One may speculate on the drainage conditions here in the future. It does not appear that the subterranean route is likely to become clogged and the route shut off. The St. Louis limestone is notable throughout its outcrop in Indiana and Kentucky for its perfection of

FIG. 5.

Fig. 5. View of the meander curve against which Indian Creek channel snugly fits just northeast of the center of section 8. (See Fig. 1.) The view shows the main part of the spur forming the neck between the two limbs of the great meander curve. It is locally known as "Boogers Point". The arrow indicates the place of the re-entrance of Indian Creek waters into the surface channel. (See Fig. 4.)

development of subterranean channels. Lost River in Orange County, Indiana, has a subterranean route 8 miles in length, having practically abandoned a surface route approximately 19 miles in length. It is possible and even probable that the subterranean route will be enlarged in the future. One may consider it as developing to the stage of an open tunnel and the formation of a natural bridge. The rock of the ridge over the subterranean route is at least 200 feet thick and is competent. The lower 150 feet of it is limestone and the remainder is sandstone. If it should ever reach the open tunnel stage, it is only a step further to the open drainage stage. Such a condition is a high probability in the course of time. Each end of the subterranean route is situated on the outside of a meander curve. These curves may be expected in time to develop, and the subterranean route thus become shorter. Such will only hasten the development of the passage way to the open tunnel stage and eventually to the open drainage stage. When it has advanced to either one of these stages the present circuitous meander channel may be abandoned. If this condition is ever attained the meander route would no longer be considered a part of Indian Creek

or Indian Creek valley. But it is more likely that the circuitous meander route will be retained through the continued action of the flood waters, as it is to be kept in mind that erosion is chiefly accomplished during high water stages in areas of topographic youth and maturity. Still another possibility is suggested by the wash on the west side of the road in the northwest quarter of the northeast quarter of section 8. Should this wash develop sufficiently the "sink" would be abandoned through the development of a surface cut-off, thus causing the abandonment of the present developing subterranean cut-off.

This drainage adjustment which is taking place through the development of an underground route across the neck of a meander loop is here called a subterranean cut-off. When once completed the result is the same as in a surface cut-off of a meander loop, whether it is in the case of a meandering stream or a meandering valley. This drainage adjustment does not well classify under stream piracy, as may be suggested and which may possibly be referred to as "self-capture". The term "self-capture" may be inferred to have a definite meaning, but in itself it is a rather impossible term. The term "subterranean cut-off" is expressive of the condition of drainage and gives a direct inference to the process, and is therefore preferable.

Indiana University.

THE HEWITT OIL FIELD, CARTER COUNTY, OKLAHOMA.

LOUIS ROARK.

Introduction.

The Hewitt Oil Field which is one of the most important fields in Oklahoma is located in the western part of Carter County, Oklahoma. The field was discovered June 1, 1919, by the Texas Company, when their well No. 1, on the A. E. Denny lease, was drilled in with an initial production of 410 barrels flowing. This well is located in the northeast corner of the NW. ¼ of the NW. ¼ of the NW. ¼ of section 27, Township 4 South, Range 2 West. This discovery well of the field is located on the south edge of the field and is now an edge well.

Since the bringing in of this well development has been very rapid until at the present time there are about 550 producing wells with an average daily production of about 45,000 barrels of oil. As yet the field has not reached its maximum production.

The writer commenced studying the geological conditions of this field for the Roxana Petroleum Corporation in January, 1920, and spent about five months' time on the work. A report was submitted the latter part of June, 1920.

At the present time the Carter Oil Company, the Wolverine Oil Company, the Westheimer and Daube interests and the Humble Oil and Refining Company are the largest producers in the field. The Carter Oil Company is leading in production with a daily average of about 9,000 barrels. The specific gravity of the oil varies from 34 degrees to 38 degrees Baume.

The writer is greatly indebted to the Roxana Petroleum Corporation for giving permission to publish this article and to Mr. R. A. Conkling, head geologist of the Roxana Petroleum Corporation, under whose supervision this work was done, for his advice and suggestions.

Location and Area of the Field.

The Hewitt field is located in Township 4 South, Range 2 West. This township is in the western part of Carter County, Oklahoma, about 25 miles north of Red River, the southern boundary of Oklahoma, and about 20 miles west of Ardmore, Oklahoma.

The field is 3 miles east of the southeast extension of the Healdton field and about 12 miles southwest of the western part of the Arbuckle mountains. The field covers an area of 6 to 7 square miles. There are 13 sections in the township with producing wells as follows: Sections 9, 15, 16, 21, 22, 10, 23, 25, 26, 27, 28, 35 and 36, of which the first five are the principal producing sections.

Topography and Drainage.

The relief of the Hewitt field proper is about 100 feet. The highest point is near the southwest side of the field in the southwest corner

of section 22, Township 4 South, Range 2 West. This point has an elevation of 929 feet above sea level and the lowest point is along the bottom of Bayou Creek which passes thru the northern and eastern portion of the field. The elevation of this flood plain is 837 feet above sea level. There are no steep escarpments along the sides of the valley. The topography may be classed as late maturity in age since the area is well drained and the larger streams have developed flood plains to some extent.

The field is drained by Bayou Creek and its tributary streams. Bayou Creek flows southeast and empties into Red River and thence into the Mississippi River.

The production in Hewitt is not confined to a major divide as in Healdton. Wells are found on the highland and also in the bottom along Bayou Creek and its tributaries.

The Hewitt field was covered for the most part with scrub oak timber, commonly known as black jack, at the time the discovery well was drilled. This timber has been greatly removed and thinned during the progress of development of the field.

Stratigraphy.

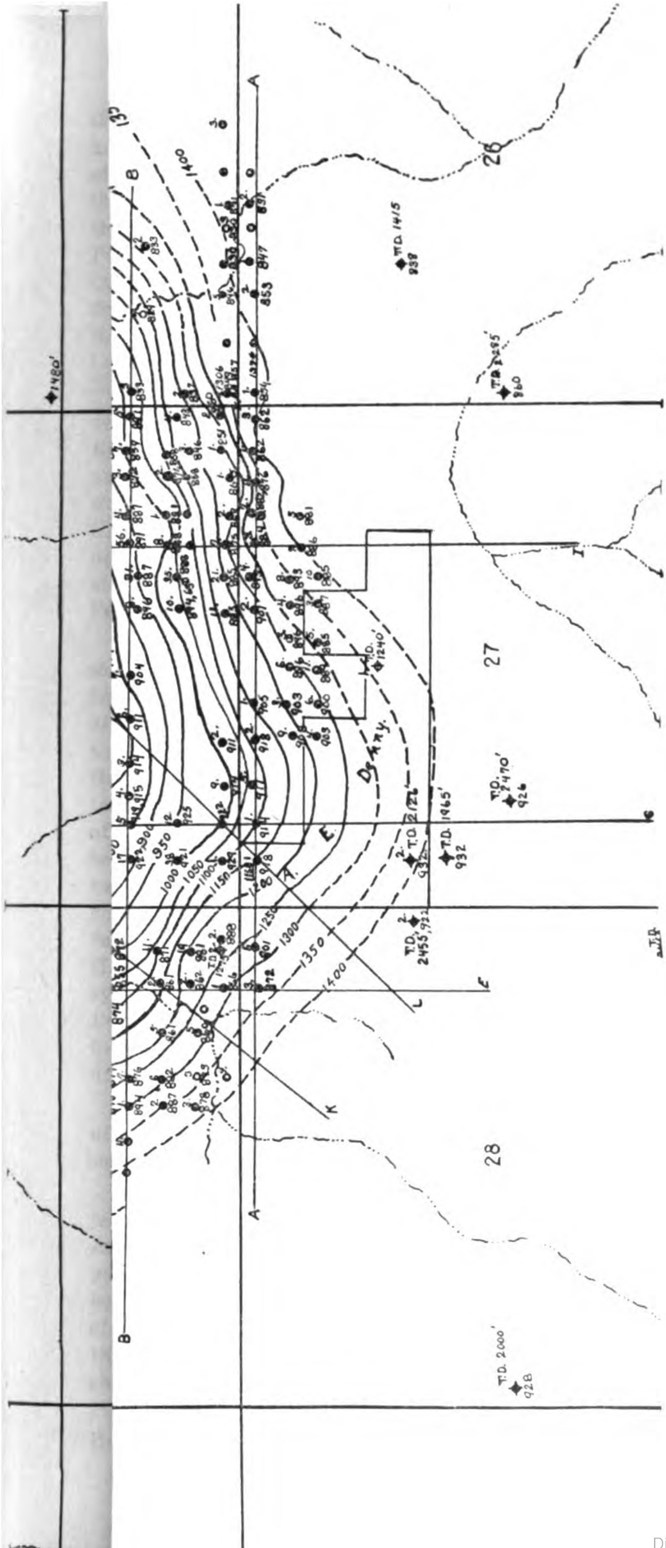
The generalized geologic section of Southern Oklahoma as given by J. A. Taff in his report on the Geology of the Arbuckle and Wichita Mountains, U. S. G. S. Prof. Paper No. 31, is shown below, and a brief description is also given of those principal formations that occur in the Hewitt field.

GEOLOGIC SECTION SOUTHERN OKLAHOMA (After J. A. Taff.)

Cretaceous	Cambrian
Permian	Pre-Cambrain
Pennsylvanian	Franks Conglomerate
Undifferentiated	Caney shale
Undifferentiated Red Beds	Sycamore limestone
Sandstones, shales, limestones and coals	Woodford chert
Wapanucka limestone	Hunton limestone
Pennsylvanian	Sylvan shale
Mississippian	Viola limestone
Devonian	Simpson formation
Siluro-Devonian	Arbuckle limestone
Silurian	Reagan sandstone
Ordovician	Igneous rocks
Cambro-Ordovician	

Cretaceous.—The Cretaceous occurs in the Hewitt field only as a capping for a few of the highest hills and consists of undifferentiated sand and gravel and is of little or no importance.

Permian.—The undifferentiated red beds of the Permian which covers the Hewitt field to a depth of 50 to 400 feet, consist of alternating beds of red, gray and white shale, and brown, white and red sandstones. The Permian is thinnest near the center of the subsurface structural high as mapped, this high being about the center of the field as now outlined. The Red Beds, as the Permian is commonly called,



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thicken rapidly toward the edges of the field and as the lower part of the anticlinal structure is reached. In the producing wells along the edge of the field, especially the south and west side, the Red Beds attain a thickness of 400 feet. The Permian thickens tremendously away from the field where the angular unconformity between the Permian and Pennsylvanian decreases. Many of the sandstones found in the Permian carry fresh water in considerable quantities. There is not a well defined basal water sand of the Permian in the Hewitt field as, in the Healdton field. (The Healdton Field, Oklahoma, by J. G. Bartram and Louis Roark. Bull. Am. Assoc. of Petroleum Geologists. Vol. 5.)

Unconformity Below the Permain.—The Permain rests upon the underlying Pennsylvanian in the Hewitt field with an angular conformity. Beneath the Permian is a thick blue shale interval with occasional sandstone and thin limestone lenses, the former carrying gas, oil and water . This blue shale is of Pennsylvanian age and steeply dipping while the Permian on the surface shows only slight dips, therefore resting upon the Pennsylvanian with an angular unconformity. The Permian on the surface dips about 30 to 40 feet to the mile while the underlying Pennsylvanian shows dips of about 1,000 to 1,200 feet to the southwest.

Pennsylvanian.—The Permian is underlain by a thick series of blue shale, sandy shale, sandstones and limestones of Pennsylvanian age, it is from these formations that the oil of the Hewitt field is produced. So far as known from present drilling records the Pennsylvanian varies in thickness from 1,200 to 2,200 feet in the Hewitt field and nowhere has the Pennsylvanian been drilled thru and older rocks penetrated. It is therefore impossible at the present writing to determine the thickness of the Pennsylvanian because of this lack of information, which can be obtained from deep wells penetrating the older rocks. The Pennsylvanian outcrops about 12 miles east of the Hewitt field where dips of 65 to 85 degrees can be observed. It is also impossible to project these formations and estimate the thickness of the Pennsylvanian in the Hewitt field because of the angular unconformity between the Pennsylvanian and the older formations below and the unconformity of the Pennsylvanian with the Permian above. In addition to these unconformities the Pennsylvanian formations have flattened out until they are dipping only about 10 to 12 degrees on the sides of the Hewitt field.

The writer has not been able to accurately determine to which part of the Pennsylvanian these shales, sandstones and limestones belong, but believes they belong to the lower Pennsylvanian or Glenn formation.

Beneath the Permian Red Beds there is a thickness of 1,000 to 1,800 feet of blue shale with sandstone and limestone lenses. These irregular sandstone lentils carry water, oil and gas and occasionally make small gas and oil wells. Immediately under this shale interval is the main body of oil and gas sands called the Hewitt Sand Zone. The thickness of this zone has not been fully determined but is about 600 to 700 feet thick, carrying one to seven sandstones interbedded with shale, sandy shale and limestone.

The lower Pennsylvanian has not been definitely identified in the Hewitt field due to either its absence or the fact that the wells have not

been drilled to sufficient depth to reach the lower member, unless the producing zone is Glenn, which is now believed to be the case.

Unconformity Below the Pennsylvanian.—So far as known the unconformity below the Pennsylvanian has not been reached by any wells drilled in the Hewitt field. The writer believes that old buried hills of rocks older than the Pennsylvanian exist beneath the Hewitt field as in the Healdton field (Unpublished data on Healdton Oil Field by J. G. Bartram and Louis Roark). Old limestone hills similar to the Criner Hills, twelve miles southeast of the Hewitt field, exist beneath the Healdton field and it is believed that a similar condition exists in the Hewitt field except that such hills are more deeply buried than in the Healdton field, where the older formations are found as shallow as 800 feet in some parts of the field. Deep drilling in the heart of the Hewitt field will eventually penetrate these old limestones making up the buried Hewitt hills. The rocks in these buried hills are believed to be sharply folded with the Pennsylvanian resting unconformably on the steeply dipping eroded edges of the earlier rocks. This is the condition in the Criner Hills southeast of Hewitt where the Pennsylvanian overlaps the earlier formations and in the Healdton field northwest of Hewitt.

Older Formations.—The formations older than the Pennsylvanian have not been identified in the Hewitt field and therefore will not be discussed here. These older formations have been fully described from a study of exposures at their outcrop in the Arbuckle Mountains, about 12 miles northeast of the Hewitt field, by J. A. Taff in U. S. G. S. Prof. Paper No. 31. (Geology of the Arbuckle and Wichita Mountains.)

Structure of the Permian.

There is a slight folding of the Permian in this area, giving a small anticlinal doming of the surface formations. The highest portion of this dome is near the section corner of sections 21, 22, 27 and 28, Township 4 South, Range 2 West. The Permian structure is probably due to a slight deformative movement after the deposition of the Permian. A small part of the Permian structure may be due to sagging and settling of the Permian.

This surface structure is a flat dome-like fold with dips of 30 to 40 feet to the mile. The discovery well of the field was drilled by the Texas Company on their A. E. Denny lease, known as Denny No. 1 well, and is located in the northeast corner of the northwest quarter of the northwest quarter of section 27, Township 4 South, Range 2 West and was well located on the surface structure for a favorable test. Due to the unconformity between the Permian and Pennsylvanian formations the discovery well was near the south edge of the field as well No. 2 on the same lease drilled by the Texas Company 1,600 feet south of No. 1 was a dry hole 2,126 feet. The writer believes that this No. 2 well should have been drilled to 2,250 or 2,300 feet before being condemned as a dry hole.

Structure of Pennsylvanian.

In studying the Pennsylvanian structure of the Hewitt field nine cross-sections were plotted on tracing linen. The oil sands were used

as a datum plane on which to draw subsurface contours. Four east-west cross-sections, three north-south sections and two northeast-southwest sections were drawn. In addition to these cross-sections the logs of all producing wells were plotted on individual graphic log forms, thus making sections in any direction available for purpose of correlation and study.

From these cross-sections and plotted logs the accompanying subsurface map was made (Fig. 1). Correlation lines were drawn on the top of the producing sands and also on the water sands above the oil sands and thru sands carrying only slight shows of oil and gas. These correlation lines on the water sands help to check the correlation of the sands, although the water sands cannot be depended upon entirely because of their lenticular nature.

These correlation lines show that the oil sands have a considerable degree of regularity, although there are some irregularities due to local thickening and thinning of the sands and also to inaccurate logs. The sands in the Hewitt field are much more regular than in the Healdton field but not as regular as in the fields of the northern part of Oklahoma.

The structure of the Hewitt field as shown by the accompanying subsurface map (Fig. 1) is an elongated dome with the long axis extending north and south, about 10 degrees west of north. The top of the dome is flat, covering about one-quarter section and dipping off steeply to the west, southwest and south. Since the completion of the accompanying map further drilling, extending the field north, shows that the Hewitt anticline has as minor structural features two domes connected by a slight saddle.

The crest of the main Hewitt dome, or the dome further south, is in the northwest quarter of section 22, Township 4 South, Range 2 West. From the apex the Hewitt sands dip steeply to the west, southwest and south. The dips to the east and north are not nearly so steep as in the other directions. However, the east and north sides of the field have not been fully limited by dry holes so the amount of dip has not been determined. The sands dip north to about the west quarter of section 15, Township 4 South, Range 2 West, where they commence to rise to the second dome located probably in the northwest quarter of section 15, Township 4 South, Range 2 West.

The principal differences between the two domes of the anticline is that the north dome is higher structurally and yields strong gas wells whereas the south dome is lower and has never produced any dry gas from the Hewitt sand.

In addition to the two minor domes on the main anticline there are indications of the presence of two faults. Along the north line of section 22-4S-2W wells are producing at considerably different depths. Either the sands dip steeply to the north forming a very sharp syncline between the two domes or else the Hewitt sand zone is faulted. The failure to find sands at depths where the Hewitt sand should occur in offset wells strongly suggests a fault with the upthrow side to the south. On the north side of the north line of section 22 in section 15 the Hewitt sand not only is found about 300 feet deeper than in offset wells to the south, but the sand is not as productive as in the wells

where found at a higher elevation. If present this fault would extend almost parallel with the north line of section 22 dying out to the west before the northwest corner of section 22 is reached. This fault may be the cause of the two structural highs with a saddle between. The presence of this fault and its extent to the east has not been verified but is strongly suggested by the records of the wells in this area.

Indications also point to a fault limiting the field on the north thru the center of section 9-4S-2W with an east-west trend. The upthrow side of this fault would be to the south. This fault is strongly suggested by wells near the center of section 9. The Humble Oil and Refining Company found a typical Hewitt section in their Hewitt-Walker No. 2, which is producing from sands found at 1,390 feet and below while just across the line to the north Merrick, et al, in their Lowery No. 1 and the Hewitt-Walker No. 1 of the Humble Oil and Refining Company drilled to depths greater than 1,800 feet, and found nothing but red beds and water sands. The fact that the Hewitt sands were not found in these two north wells makes it almost certain that a fault with an east-west trend exists.

Future drilling will be necessary to prove the presence and extent of these two faults. However the writer believes that they exist and will have an important bearing on the limits of the field to the north and northeast.

The Hewitt anticline is very steeply folded. The formations dip west, southwest and south from the crest of the anticline at the rate of 1,200 to the mile. As mentioned above the east and north dips have not been fully established. The producing formations are more steeply folded in the Hewitt field than in any other producing field in Oklahoma with the possible exception of the southeast extension of the Healdton field where dips equally as steep in the producing sand have been observed by J. G. Bartram and the writer (Fig. 1, p. 472, Bull. Am. Assoc. of Petroleum Geologists. Vol. 5).

The Hewitt sands are of Pennsylvanian age, probably the Glenn formation, and are believed to have been deposited over and around a core of older rocks as is the case with the Healdton sands and were folded with the older rocks before the Permian was laid down and possibly again slightly folded after the deposition of the Permian. To date the Pennsylvanian has not been penetrated and the older formations discovered or at least they have not been identified. The Pennsylvanian is at least 2,000 to 2,100 feet thick at Hewitt.

A small part of the dip on the structure may possibly be due to settling and sagging of the Pennsylvanian sediments about a core of older rocks. The structure is due primarily to deformative movements after the deposition of the Pennsylvanian. This is shown by the steep dips of the Pennsylvanian producing sands and the angular unconformity beneath the Permian.

Source of the Oil.

The oil of the Hewitt field and also of the Healdton field has come from either the Pennsylvanian shales and limestones and the asphaltic sands near the base of the Pennsylvanian, or from the Caney shales of

Upper Mississippian age, or from the Simpson formation of Ordovician age.

No doubt much of the oil, and possibly most of it originated in the Pennsylvanian shales and limestones and the Caney shale of Mississippian age where present. These shales are dark and appear organic which, with the presence of limestone, indicates plenty of organic life at the time of deposition for the formation of a considerable quantity of oil and gas.

The Simpson formation may have been a very important source of oil in the Hewitt and Healdton fields. This formation is known to carry oil in the Healdton field as there are two wells producing oil from sands of Simpson age at a depth of about 2,700 to 2,775 feet. The Simpson formation has much asphalt and other evidences of oil at its outcrop in the Arbuckle Mountains. This formation seems to have carried oil in great quantities and may have given up large amounts to the overlying Pennsylvanian sands thru faults, fissures and unconformable contact with the Pennsylvanian sands.

The regional movements which occurred in Pre-Pennsylvanian times before the deposition of the Pennsylvanian caused very extensive folding and faulting. These movements were followed by erosion over a long period which exposed the earlier rocks along the crests of the anticlines. The Pennsylvanian was then deposited upon these eroded upturned edges of older rocks and no doubt in direct contact with the Simpson and other oil forming formations. This made conditions ideal for the migration of oil from the older eroded beds into the overlying Pennsylvanian reservoirs from which the oil is now produced. This migration took place across the unconformity from the older oil bearing formations and also thru the faults which no doubt existed.

Oil Sands.

In addition to the main Hewitt sand which has produced most of the oil to date there are other oil and gas bearing sands. These sands will be discussed in order from the top down.

Shallow Gas Sand.—The shallow gas sand has produced considerable gas from wells drilled to it. This shallow sand is found on top of the structure at depths varying from 250 to 400 feet and lies about 1,000 to 1,050 feet above the Hewitt sand. These shallow wells produce from 100,000 to 3,000,000 cubic feet of gas per day. This gas was of considerable importance on account of the shortage of gas in the field and was used for operating purposes. Many of the gas wells in this shallow gas sand were short-lived and soon became exhausted. The sand varies considerably in thickness but has an average thickness of about 20 feet. Further down on the flanks of the structure this sand either produced water or was cut off entirely by the unconformity between the Permian and Pennsylvanian.

The 600 to 700 Foot Gas Sand.—A second shallow gas sand has been found 600 to 700 feet, which has produced some good gas wells. The wells which produce gas from this sand have an initial production from 3,000,000 to 10,000,000 cubic feet of gas per day. For the most part the wells in which this gas is encountered are bradenheaded and

the gas produced between the ten and twelve inch casing. The gas is then used for operating purposes while the well was then drilled to the oil sand. This sand is lenticular in character and varies considerably in thickness. The depth at which this sand is found varies with the position of the well on the structure and with the elevation of the well. If the well is on top of the structure the sand is found at a much shallower depth than when located off the top of the structure. The sand lies almost uniformly 625 to 650 feet above the Hewitt Sand Zone.

Stray Oil Sands.—There are several stray oil sands found above the Hewitt sand and below the 600 foot gas sand. These sands vary from 70 to 300 feet above the Hewitt sands. These sands are not regular and are of but small extent. Wells drilled to these stray sands vary greatly in initial production, and do not hold up in the amount of oil produced for very long. The initial production of wells drilled to these sands is from 25 to 200 barrels per day.

Hewitt Sand Zone.—The Hewitt Sand Zone includes a zone 600 to 700 feet in thickness made up of oil bearing sands, shales, sandy shales and dry sands but no water sands occur in this zone.

The first or main sand in the Hewitt Sand Zone has been the main producing sand in the Hewitt field. This sand is surprisingly continuous and is the datum used in making the subsurface structure map of this area. This first or main sand was the principal producing sand until November, 1920, when deeper drilling showed that some of the deeper sands were of more importance. This main sand is found in wells on top of the structure as shallow as 1,200 feet in the north central part of section 22-4S-2W and as deep as 2,100 to 2,300 feet along the north line of section 27-4S-2W. This sand dips at the rate of 1,200 feet to the mile to the west and 1,000 feet per mile toward the south.

The Hewitt Sand Zone is capped by a blue shale interval of about 400 feet with hardly a break. This shale separates the oil sands and the higher water bearing sands and also prevents the migration upward of the oil thus leaving the sands of the Hewitt Zone barren of oil.

The sands of the Hewitt Zone are soft, porous, and usually white and gray in color. The sand varies in porosity and size of grains. This variation in porosity and in the size of grains accounts for the difference in production of the various wells. The heaviest production comes from wells where the sand is fine grained and loose. The lighter production comes from sands with coarser grains and more firmly cemented but still comparatively soft.

Deeper sands in the Hewitt Sand Zone have been found to be of considerable importance. The intervals to these deeper sands are not constant due to the lenticular character of the sands. A few sands of importance have been found which persist with fair regularity in most parts of the field.

A second sand of importance about 75 to 100 feet below the main or top sand has been found in most parts of the field. In all cases this sand, when drilled into, increases the production of the wells. Occasionally in some parts of the field this sand is more prolific than the main sand. This sand when wells are deepened to it increases the production 20 to 100 barrels per day.

The next sand of any importance and regularity lies about 150 to 200 feet below the top or main sand of the Hewitt Sand Zone. This third sand in nearly all cases increases the production of wells when penetrated. This increase in production is from 25 to 200 barrels per day.

A fourth sand occurs about 275 to 325 feet below the top or main sand, which also increases production considerably in the wells which have penetrated it. This sand probably increases production around 100 to 200 barrels per day.

Another sand is found at about 400 feet below the top sand which increases production about 200 to 300 barrels. This sand may be called the fifth oil sand of the Hewitt Sand Zone.

The sixth oil sand probably will prove to be one of the most prolific sands of the zone and is found at about 600 to 650 feet below the top sand of the Hewitt Sand Zone. This sand has produced as much as 400 barrels per day in some of the few wells drilled to it.

The deepest producing sand stratigraphically in the Hewitt field is the seventh sand of the Hewitt Sand Zone and is found about 700 feet below the top or main sand. This sand will probably increase the production in the wells which have penetrated it 100 to 200 barrels.

Further exploiting of the sixth and seventh sands may prove them to be the most prolific sands of the Hewitt field.

There is no data available with which to predict whether there are deeper sands in the Hewitt field than this seventh sand. If there are deeper sands we are not able to predict whether they will carry oil or water.

No sands in the Hewitt Sand Zone have been found which carry water in the field and this factor will make it easy to produce from all sands without endangering the upper sands by permitting water to enter the sands. It will be a very easy matter to deepen the wells and produce from two or more sands in the same well.

Water Conditions in the Hewitt Field.

There are three sources of water with which the oil man has to contend, namely: (1) upper water, (2) edge water or water in the base of the sand and, (3) bottom water or water in a separate sand below the oil sand.

To date the first or upper water is the only source of water with which the Hewitt operator will have to deal. This upper water is easily taken care of by casing off the water before the oil sand is penetrated.

At the present writing there are only three or four wells in the Hewitt field making water along with the oil and these are known to be due to casing leak, that is, the casing failed to shut off the water or a leak has developed in the casing from some cause and permitted this upper water to enter the well.

Eventually edge water will make its appearance in the field and will have to be taken care of. This will first make its appearance in the wells along the edge of the field and migrate in on the field as the sands are drained of their oil.

Bottom water may make its appearance as deeper drilling continues and then will have to be shut off by one of the various methods of plugging or shutting off bottom water commonly used in the oil fields. The methods used in plugging and shutting off water will not be discussed in this article.

Oil Production.

There are about 550 wells producing in the Hewitt field with an average daily production of 45,000 barrels of oil. The average daily production per well in the Hewitt field is about 80 barrels. This average exceeds the average per well of any other field in the state. No doubt the average daily production of the wells could be greatly increased by the deepening of a great many of the wells in the field. The wells range in initial production from 50 to 2,000 barrels per day.

A Zone of Large Concretions in the Knobstone.

W. M. Tucker.

My attention was recently called to a peculiar and interesting bed of concretions in the Knobstone of Monroe County. The deposit is very local in its distribution. It occurs in two ravines in sections 1 and 2, T. 10 N., R. 3 W., in the northwest corner of Monroe County. The two ravines head on the Harrodsburg limestone near the middle of sections 1 and 2 and extend northward, immediately entering the Knobstone with the characteristic rapids and small waterfalls. The main ravine (west) has a depth of seventy feet one-fourth of a mile from its source, and the smaller one (east) attains that depth in a shorter distance. The larger ravine enters the concretionary zone thirty-five feet below the contact of the Harrodsburg and Knobstone. The zone is

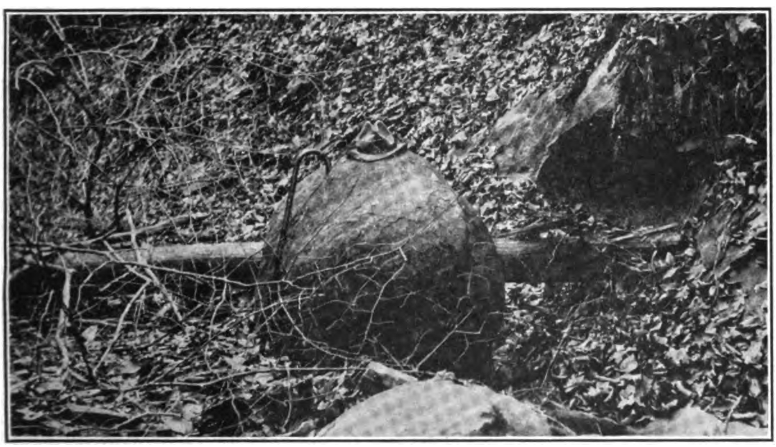

FIG. 1.

Fig. 1. A concretion five feet in diameter which has been dislodged from the ravine wall in the background.

fifteen feet thick. The concretions can be seen in the ravine walls for about one-fourth of a mile, just south of the Monroe County line (Figs. 1 and 2). The bottom of the ravine is strewn with concretions and fragments for this distance. Only four were found in the smaller ravine which at this point is about one-quarter of a mile east. None were found in the other ravines of the neighborhood.

The concretions vary in size from a fraction of an inch to five feet in diameter. They show none of the concentric structure which is displayed in some concretions. No distinct nucleus was discovered in any of them. The composition of the concretions is highly silicious, especially those in the upper part of the zone. Those in the lower

FIG. 2.

Fig. 2. Three concretions, each about two feet in diameter, in place in the ravine wall.

part of the zone contain considerable calcium, iron and aluminum. An examination of a specimen from the extreme top of the zone under the petrographic microscope resulted in the following estimate of contents: quartz, 8/9; calcite, 1/9; traces of limonite, pyrite and kaolinite. A chemical analysis of a specimen from the lower part of the zone gave the following results:

SiO_2	46.48 %
CaO	17.92
$\left.\begin{array}{l}Fe_2O_3\\Al_2O_3\end{array}\right\}$	19.87
MgO	.395%
CO_2	14.69
SO_3	.08
Total	99.435%

The concretions of this zone resemble those of the Olentangy shale of Ohio in size, mode of occurrence and general appearance but those of the Olentangy shale are of very wide distribution. Beds of limestone occur in the Knobstone south and east of this zone at about the same horizon. Small concretions are found at many horizons in the Knobstone. So far as known there is no relation between this bed of concretions and the concretions of other parts of the Knobstone nor do they seem to be related to the limestone beds. So far as known there is no similar zone of concretions in the Knobstone or elsewhere in Indiana.

Acknowledgement is made to Prof. W. N. Logan who made the petrographic estimate, Mr. Luther S. Ferguson, who made the chemical analysis, and Mr. Arch R. Addington, who developed and mounted the pictures.

Indiana University.

Decrement Measurements.

R. R. Ramsey

In wireless work one of the important measurements is the logarithmic decrement of the aerial or decrement, as it is called in wireless. Decrement is an indication of the sharpness of the radiating wave. To liken radiation from a wireless station to the radiation from a light source: a station with a low decrement gives a line spectrum of a definite wave length while a large decrement means a band spectrum covering a large range of wave lengths. It is hard, or next to impossible to tune out a station with a large decrement. On this account the U. S. Government has outlawed stations with decrement greater than .2. Another advantage of small decrement is that all the radiated energy of the sending station is concentrated on one wave length, while the energy is scattered over a broad band when the decrement is large.

The solution of the differential equation of an oscillating circuit containing resistance, inductance, and capacity may be put into the form $I = I_0 e^{-\alpha t} \sin wt$ where I_0 is the initial or maximum value of the current, I is the value of the current at any time, t; w, is the angular velocity or $2\pi n$, n being the frequency and, $\alpha = R/2L$, R being the resistance and L the inductance of the circuit.

The equation can be represented by the curve of figure 1.

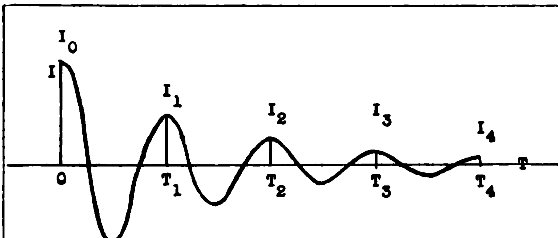

Fig. 1.

The amplitudes are:

$I_0 = I_0 e^{-\alpha 0 T}$

$I_1 = I_0 e^{-\alpha T}$ and $\dfrac{I_1}{I_2} = \dfrac{I_0 e^{-\alpha T}}{I_0 e^{-\alpha 2T}} = e^{\alpha T}$

$I_2 = I_0 e^{-2\alpha T}$ $\dfrac{I_2}{I_3} = \dfrac{I_0 e^{-\alpha 2T}}{I_0 e^{-\alpha 3T}} = e^{\alpha T}$

etc.

$$\frac{I_n}{I_{n+1}} = e^{\alpha T}$$

From this $\alpha T = \log.\frac{I_1}{I_2} = \log.\frac{I_2}{I_3} = \log.\frac{I_n}{I_{n+1}}$. This is the same as the usual logarithmic decrement used in ballistic galvanometer work, except in ballistic galvanometer work we follow the English fashion of taking the ratio of the two successive swings in the opposite direction instead of the two successive in the same direction. Or the decrement in U. S. wireless is two times the value determined by the English method. The determination of I_1, I_2, etc., or successive amplitudes of the current is impossible where the frequency is in the order of 1 million, as it is in wireless work.

In the above equation the frequency $n = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$.

If R is small or zero, this becomes $n = \frac{1}{2\pi\sqrt{LC}}$. This is the same value for n obtained from the equation of alternating current in a circuit containing resistance, inductance and capacity, with an alternating e.m.f.

$I = \frac{E}{\sqrt{R^2 + (1/Cw - Lw)^2}}$ The value of I is a maximum when $1/Cw - Lw = 0$, i.e. $I = E/R$. If $Lw = 1/Cw$, then $(2\pi n)^2 = 1/CL$ or $n = \frac{1}{2\pi\sqrt{LC}}$.

The above equation for I can be written $I^2 = \frac{E^2}{R^2 + (1/Cw - Lw)^2}$.

When the reactance term $1/Cw - Lw = 0$ the circuit is in resonance with the e.m.f. Then $I^2_r = \frac{E^2}{R^2 + (1/C_r w - Lw)^2} = \frac{E^2}{R^2}$ where C_r is the value of the capacity which makes the circuit in resonance with the e.m.f. Then $Lw = 1/C_r w$.

If the capacity is changed until $I^2 = 1/2\ I^2_r$, I^2_r being the resonance value, then $1/2 I_r = \frac{E^2}{R^2 + (1/Cw - 1/C_r w)^2}$ and $2R^2 = R^2 + (1/Cw - 1/C_r w)^2$ since doubling the denominator will halve the value of I^2. Then

$R^2 = 1/w^2([C_r - C]CC_r)^2$ or $R = 1/w(C_r - C/CC_r)$

$T = 1/n = 2\pi/w$ and decrement $d = \alpha T = R/2L\ T$.

$$d = \frac{R}{2L}t = \frac{1}{w}\left(\frac{C_r - C}{CCn}\right)\frac{2}{w2L} = \pi\left(\frac{C_r - C}{C_r}\right)\frac{1}{w^2}\frac{2}{2CL}.$$

$d = \pi\frac{C_r - C}{C_r}$ where C_r is the value of the capacity at resonance and C is the value of capacity which reduces the mean square of the current to 1/2 its value. In this manner the decrement is measured by determining the resistance in terms of a capacity.

The decremeter consists of a coil, a variable condenser, and a radio frequency milliammeter or galvanometer connected in series and placed near the radiating source. The capacity is varied until the current is a maximum or the circuit is in resonance with the source. The capacity of the variable condenser is varied until the mean square of the current is reduced to 1/2 the first value. Then the decrement is calculated. This gives the sum of decrement of the source, ærial, and the decrement of the decremeter. This is exactly the same as in measuring the resistance of a 1 to 1 transformer circuit by introducing resistance in the circuit until the current is made 1/2. The value of R introduced is equal to the sum of the resistances in the two circuits. This holds if the mutual inductance is large as in a transformer.

Since $d=\alpha T=(R/2L)T$, doubling the resistance in either circuit will double the decrement of either circuit.

Thus the introduction of resistance in the decremeter circuit until the current in the decremeter is made 1/2 half, the circuit being kept in resonance all the time, will double the decrement of the decremeter. Then if $D_1=d_1+d=$ first decrement measurement and $D_2=2d_1+d=$ second decrement measurement with resistance inserted in decremeter circuit. Then $d_1=D_2-D_1$.

The decremeter is assumed to be loosely coupled to the aerial so as not to affect the aerial circuit. The method is much more simple than that usually given, as in formulae 63 and 64, page 94, Radio Instruments and and Measurements, Circular of the Bureau of Standards No. 74. This formula is:

$$\delta^1 = \frac{2\delta\delta_1+\delta_1^2-\delta^2}{\delta-\delta_1}$$

Where δ^1 is the decrement of the aerial, δ the decrement of the wave meter and δ_1 the increase of δ due to the resistance added which reduces I_1^2 to $1/2\ I^2$.

δ^1 the decrement of the aerial seems to be given in terms of two unknown quantities. The remark is made, "It should not be forgotten that these formulae apply only when the coupling is very loose and both decrements are small". This is the condition assumed in the derivation of my formulae.

The most accurate method of getting the decrement of a decremeter is to use a continuous wave current such as is generated in the modern tube circuits or wireless telephone circuits. In these circuits the wave is continuous or the decrement is zero and the decrement measured is that of the decremeter alone.

This method can be used to determine the decrement of the decremeter and thus check the above method.

The decremeter used contained a 250 milliampere milliammeter whose D. C. resistance was 6 ohms.

When the current in the decremeter was large there was a tendency to spark over in the condenser. This brush discharge introduced a resistance in the circuit which was more or less variable. This tends to make the decrement of the decremeter greater at 200 milliamperes than at 100 milliamperes.

Due to the fact that the current is intermittant in a damped wave station. This sparking over effect is greater with damped waves than in the case of continuous waves.

The following table gives results with CW and damped waves. Decrement of wave meter at wave length indicated.

	100 mil. amp.	200 mil. amp.	
390 meters	.11	.14	
375 meters	.10	.15	
375 meters	...	.15	
348 meters	.10	.14	
310 meters	.12	.14	Average $\delta_1 = .126$

Decrement of decremeter with resistance introduced to reduce the current from 200 to 100 milliamperes.

100 milliamperes	375 meters
$2\delta_1$	.24
.26	.27

Average $\delta_1 = .127$

Decrement of decremeter with damped wave 375 meters.

$$D_2 = 2d_1 + d = .36$$
$$D_1 = d_1 + d = .23$$
$$D_2 - D_1 = d_1 = .13$$

Second:

$$D_2 = 2d_1 + d = .38$$
$$D_1 = d_1 + d = .24$$
$$D_2 - D_1 = d_1 = .14$$

Thus it is shown that the above method of determining the decremnet of a decremeter checks fairly well with the CW. method.

Indiana University.

Studies of the Biology of Freshwater Mussels.

III. Distribution and Movements of Winona Lake Mussels.[1]

William Ray Allen.

Introduction.

Many summers have been more or less devoted to the study of lake Unionidae by the writer. An account of the feeding mechanism and survey of the food materials was published in 1914. A further study of ingestion, food selection and digestion by experimental methods appeared in 1921. While attempting to account for the assortment of food material, further study was made of the distribution and effectiveness of the organs of special sense. A paper on reactions to chemical and physical stimuli is now ready for the press. Some of the statements which are made in the following pages, e. g. reactions to light and pressure sense, are based upon data fully discussed in the above paper and may here seem arbitrary. To what extent the animals assume a definite place in the lake in response to these physical and chemical stimuli, it is the province of the present paper to show.

Previous Survey. Headlee and Simonton's careful exploration of the mussels of Winona Lake ('03) revealed eight species—*Lampsilis luteolus, L. subrostratus, L. glans, Micromya fabalis, Quadrula rubiginosa, Anodonta grandis, A. edentula* and *Margaritana marginata.* I have translated from the synonymy of Call ('99) to that of Simpson ('99). In many summers' collecting I have added but one species and only a single specimen—*Quadrula plicata,* 175 mm. in length, taken off Yarnell's Point. It is a river form, and having no direct access from the outlet on account of the dam, it probably owes its introduction to an accidental fish host or to human agency.

Headlee and Simonton state that *Lampsilis luteolus* and *Anodonta grandis* greatly outnumber the other species. They show that the mussel zone lies upon or near sandy and gravelly banks; that distribution toward the shore is limited by waves and muskrats, and outward by the soft character of the bottom. Furthermore they believe that the "black marl" of the deeper water destroys any mussels which go too far out by stopping up the gills.

The *Anodontae* were found by Headlee and Simonton in the edge of banks where sand and mud intergrade, *edentula* being more of a mud-dweller than *grandis. Lampsilis luteolus* was found to be the most cosmopolitan, found principally upon sand and gravel. *Fabalis* and *glans* occurred in deeper water, on relatively firm bottom. *Subrostratus* inhabited the outer portion of the range of *luteolus.*

[1] Contribution from the Zoölogical Laboratory of Indiana University No. 188.

These authors discuss the possible factors governing distribution, and reject all except three—enemies, wave action and bottom. I shall refer again to this portion of their paper, and discuss these factors in order.

THE HYDROGRAPHY OF WINONA LAKE.

Winona Lake is one of the many kettle hole lakes of the region. It lies in the center of Kosciusko County, in the mid-northern portion of Indiana. It has a maximum length of two miles, and averages three-fourths mile in width. Gently undulating moraines in alternation with flat peaty, or mucky, areas which represent in large measure extinct marsh or lake, prevail in the surrounding terrain.

The northern and eastern shores of Winona Lake lie close to gravelly moraines, and the middle of the western side even more closely. The southern and northwestern shores are separated from high ground by more extensive flat areas, which are but little above lake-level, and have gone through the lake-marsh succession. In the case of this lake the process of degradation through the erosion of the outlet has been arrested by a dam. Just prior to the mussel survey by Headlee and Simonton much dredging had been done at the east, south, and northwestern portions of the lake. (Fig. 1.) This resulted in a rather profound alteration of the bottom in some parts, and the elimination of some mussel beds.

Sugar Creek, Cherry Creek, and Pocahontas Creek, springs, and artesian wells are the principal sources of the incoming water. The outlet is a creek two miles in length which enters the Tippecanoe River below Warsaw. Since the tributaries are small, though steady, mussels have not gone above the lake. The latter is purely lacustrine in form and marks the upper limit in its drainage system for all bivalves except Sphaeriidae. Such has not always been the case, for I have found shells at least two miles up Pocahontas Creek. We should expect a rather small number of species so near the headwaters of Walnut Creek. Nor should we expect to find river mussels so far up.

Since the lake level has been held nearly constant for many years, the shore line has been well stabilized. Also the wave cut terrace is now well established, and in most parts of the lake its margin is sharply set off from the abysmal portion of the lake in accordance with the angle of rest of its component materials. Thus the ten and twenty foot contours parallel the shore most closely of all. (Fig. 1.) Wave action is still at work reducing the sharp points of the shore line, and the most sandy and gravelly parts of the terrace are these exposed points; while in the coves the bottom merges into mud at a much slighter depth. The prevailing storms are northwest. This is correlated with the fact that the wave cut terrace of the east shore is everywhere wider than others, and that the contours of the west shore lie closer together. Except for the sheltered situations the east terrace is swept freer of mud, which is distributed farther out in the lake. The southern corners of the lake have not yet recovered from the dredging of twenty years ago. The south shore receives the wind and waves obliquely from the northwest,

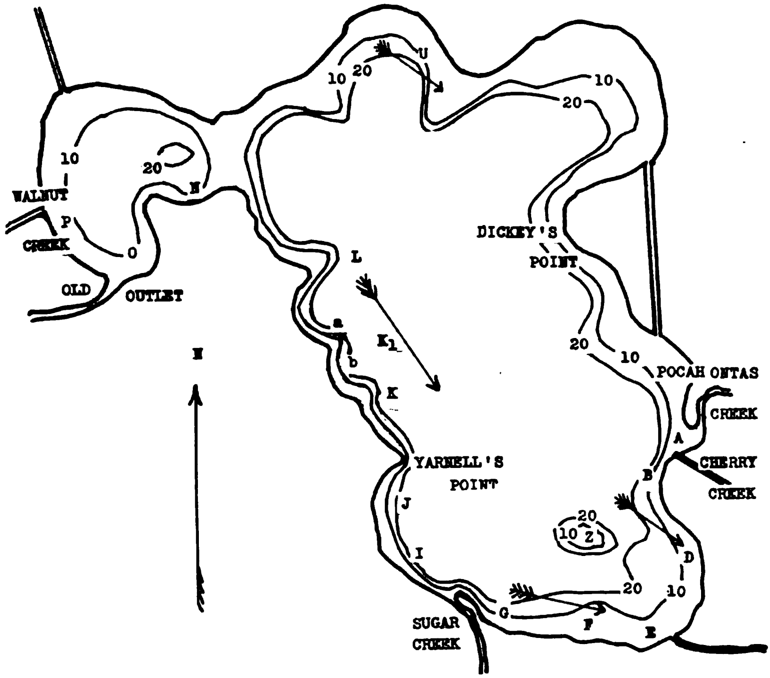

Fig. 1. Winona Lake, Indiana. Ten and twenty-foot contours shown. Letters represent stations referred to in text. Arrows are shore currents.

hence a slow distribution of its mud toward Boys' City Bay (Scott, '16, p. 14, map) and a rather firm bottom results.

The terrace constitutes a shelf of rather moderate depth surrounding the lake. This is the principal habitat of the mussel population. Baker ('16) and others have recorded the occurrence of the maximum population on the most exposed points of the shores of lakes. This generalization holds for Winona Lake except at its extreme leeward corner—Boys' City Bay—where the drift, marl, and mud from all parts of the lake accumulate and are graded out within a short distance from the shore. Kosciusko beach (Map, B) is the most exposed part of the shore line. Here in spite of much intensive collecting it continues to be one of the most populous areas of the lake bottom.

Factors Governing Distribution in Winona Lake.

Having in mind the character of the lake it will now be pertinent to examine the facts of distribution and the possible factors limiting the same. We will first consider the three accepted by Headlee and Simonton.

(1) *Muskrats.* These animals are known to depopulate small areas of mussel beds. Where occurring in sufficient number it is possible that they very definitely limit the shoreward extension of the same. However at the present time there are too few muskrats here to have a significant effect, except locally, about the mouths of creeks in particular.

(2) *Wave action.* Despite the lack of predatory enemies, mussels are uncommon on wave-swept beaches or elsewhere at two feet depth or less. Headlee and Simonton found numerous individuals thrown up on the beach following storms, and concluded that this is the manner in which their shoreward distribution is limited. The writer has seen very few such cases except those thrown up by human agency. Recently dead *Anodontae* sometimes float to the surface and are swept ashore, thus entitling them to the vernacular name of "floater."

The writer placed mussels experimentally in water of a few inches depth near the shore at various points about the lake. Sooner or later they were sure to turn and seek greater depths, oriented by a pressure sense. This movement is expedited in times of storm and high waves. The explanation is a matter of stimulation or annoyance by the moving water and sand in suspension. In protected areas the return to deep water is more leisurely.

(3) *Bottom.* The above authors have very clearly shown how the several species are limited to the respective types of bottom in the lake. The matter of preference of certain types of bottom is a function of shell weight, at least in part. The *Anodontae* alone are found sometimes on muddy substrata, while the other species are sand dwellers, all having also moderate shell weight and erect posture. In the paper referred to in the introduction experiments along these lines will be described.

During recent years no *Margaritana marginata* have been obtained from the lake. Almost no *glans* and *fabalis* have been seen. Rather few *subrostratus* and *rubiginosa* have been taken, and in both cases have been confined to small groups of individuals in a few localities. *Subrostratus* has been collected always in rather deep water off exposed points. Since so few localities of the favored type occur, we may thus account in part for their small numbers.

The western shore is so inclined to the prevailing northwesterlies that southward shore currents are set up. (Fig. 1, arrows.) Thereby even the wind has a share in determining mussel distribution, locally. (Scott, '16, map opp. p. 14.) On every point of land this shore current picks up the mud from the northern margin and deposits it on the southern fringe of the same point, in the quieter water of the lee slope. Thus the beach has an alternation of sand and mud bottom on the west shore, arranged in serrate outline. The effect on mussel distribution may be seen with the help of the map (Fig. 1) and the table. A census of the two dominant species at various points demonstrates that not only general distribution, as shown by Headlee and Simonton, but also the minute local distribution is largely a matter of the character of the bottom.

In the following table the records represent all the mussels found at a depth of from three to four feet, for a distance of a few rods, and on bottom areas selected at random. In all cases where sand is abundant *luteolus* predominated, and was nearly wanting on soft bottoms. *Anodonta* occurs often on sand, but oftener on mud or marly sand. Headlee and Simonton's zones are thus shown not to correspond at all to contour lines, for the physiographic agencies which assort the bottom materials are complicated on the west shore by the action of the shore currents.

This is also observable at one point on the east shore—the north side of Boys' City Bay—(Map, D) and at one point on the north shore, (Map, U) which lie somewhat parallel to the prevailing winds.

TABLE I.

Correspondence of Species to Type of Bottom.

Section	Anodonta grandis present	Lampsilis luteolus present	Bottom character	Remarks
D	18	23	Marly sand Marly mud	....
O	31	2	Very soft	....
I—K	14	39	Sandy	....
E	10	6	Soft marl	All small
K_1	a 9	12	Marly sand	
	b 31	16	Marly mud	See Figure 1
L	42	52	Marl, mud	....
Z	3	33	Firm, marly sand	"Sunken Island"

Section K_1 will illustrate very well how the gradation in bottom is followed in the distribution of the two species. (Table I and Fig. 1.) The sandy portion has fewer *Anodonta* than *Lampsilis*, while the adjacent muddier part has twice as many *Anodonta* as *Lampsilis*. Section L is subject to similar comparison. Such comparisons can be made between areas in the above table, except Section E.

Headlee and Simonton relate that mussel beds at Stations E to I were covered twenty years ago with mud from dredging operations. To this day many dead shells are found in those areas, and few living mussels. I was long at a loss to explain the occurrence of so many dead shells where there were almost no live ones. Even today they have secured a new foothold only in the more or less exposed places (e.g. Section G.)

The extremely soft bottoms of the canals and Section N of the lake are inhabited by Sphaeriids, but not by Unionids. In the latter some dead shells are found.

Evermann and Clark's observations of the distribution in Lake Maxinkuckee ('17) show that there the greater part of the bivalve population lies within the shoreward contours, and that deeper dredgings bring up more *Anodonta* than *Lampsilis*. Baker ('18) finds by far the greater part of the invertebrate life of Oneida Lake within the six foot contour, the bivalves lying more deeply than the other invertebrates. My collecting in Winona Lake shows that the mussel zone of Winona Lake is in somewhat shallower water. We might expect this in a small kettle hole lake, whose littoral is chiefly a wave cut terrace, going off sharply into deeper water at its outer margin, and itself averaging less in depth than in such a lake as Oneida. Being formed by waves and currents, it tends to be shallower and narrower in lakes too small for large waves. Headlee and Simonton's map indicates that the mussel life belongs predominantly within the ten-foot contour. While they found live mussels out to a depth of twenty-two feet, the deeper ones were all narrowly limited to exposed points, which the undertow keeps swept clean, and on the lee shore, where the thermocline may sometimes be depressed. Aeration and food must be better at such points than at others of equal depth.

Needham and Lloyd's Figure 191 is likely to mislead one to regard the 10-20 foot zone as the most productive in Winona Lake.

River mussels, as well as lake forms, have preferred types of bottom, hence "shoals."

Having in the main corroborated Headlee and Simonton's analysis, with respect to the three factors given above, and compared the present situation with that of fifteen years ago, let us consider some of the factors ignored or rejected by them.

(4) *Sex* can be eliminated. Both males and females seem to occur over the entire range.

(5) *Age* is probably pertinent. First because juveniles are rarely collected on the grounds where adults are most abundant. In the second place, while adults are prevalent on certain types of bottom, some of them must have migrated thither, for the host fishes of course do not drop the young mussels upon selected bottom. It will be interesting to learn the evolution of the parasitic habit of the bivalves, the origin of specific infection, and the correspondence in preferred habitat between given mussels and their respective hosts. The matter of age is very uncertain due to the rare finding of juveniles.

(6) *Pressure* has been shown (in paper No. II of this series) to initiate and to govern the movements of mussels. Their distribution is partly due to this factor. It is probably of greater importance inshore than in deep water. The pressure difference within a few inches of the surface must be greater than differences of several feet in deep water, at the outer limit of the range. Physiologically the change from twelve inches to six inches should be the equivalent to a change from twelve feet to six feet. The most active movements of mussels actually take place in water of slight depth.

(7) *Light* has a directive influence upon the movements which may sometimes affect distribution. The experimental demonstration is discussed in the above named paper.

(8) *Relation to the Epilimnion.* The above factors without further additions are sufficient to account for the adjustment to favorable environment. Yet it is at least a happy coincidence that the most suitable bottom, depth, etc., occur in the epilimnion. Otherwise mussel life would have been impossible. Food supply, temperature, and oxygen are at the optimum where the bottom is also most favorable. Furthermore these conditions are best fulfilled during the summer months, the time of highest metabolic activity of the animals.

The thermocline of Winona Lake begins at a depth of fifteen to twenty feet. Therefore the contours which represent its contact with the lake bottom are quite near the boundary of the wave-cut terrace. The terrace is thus washed by the epilimnion only, and the hypolimnion lies wholly outside the terrace. Conversely, the greater part of the lake bottom lies beneath the hypolimnion. These facts are of importance to the mussels in the ways mentioned above.

(a) *Temperature.* The development of a thermocline due to the thermal resistance of water to mixture results in the maintenance throughout summer of low temperatures below its level. Instead of a distribution of the heat of summer throughout the water, the epilimnion

receives most of it. Its temperature is therefore much higher than if the heat became distributed vertically, and higher than when the lake becomes holothermous in autumn. This results in a heightened metabolic rate on the part of the inhabitants of the epilimnion, while the abysmal bottom on the contrary is rendered unfit for the production of many living things.

(b) *Oxygen, Carbon Dioxide, and Carbonates.* The water of the epilimnion receives most of the sun's energy that is not reflected from the surface. Only here is photosynthesis effective, and here the phytoplankton has evolved methods of flotation which keep the lake's minute inhabitants mostly near the surface. For these reasons oxygen production is virtually limited to the epilimnion. Currents due to wind are set up which distribute the epilimnetic water from one part of a lake to another. The return currents pass underneath, next to the thermocline. For mussels the situation is perfectly adapted to secure well oxygenated water so long as they remain above the level of the thermocline. Yet even more striking than the oxygen curve of Winona Lake is the increase of the carbon dioxide. (Scott '16, p. 34.)

Were a lake bottom in the hypolimnion entirely suited in other particulars to support mussel life, the conditions of temperature and oxygen would make it virtually uninhabitable. *Sphaerium* has been collected from bottom of various depths down to eighty feet, where, during summer, it exists under almost anaerobic conditions.

The increase in acidity as we read downward in a lake means a corresponding reduction of the available carbonates, which is of importance in shell formation. Most of the marl deposition occurs in shallow water. The lime cycle is a function of the epilimnion almost wholly.

In all respects we may say that the stratification of a lake tends toward increasing the habitability of the epilimnion at the expense of the hypolimnion. The turnover in autumn is rendered harmless to mussels through the thorough mixing, and through the temperature reduction.

(c) *Food Supply, etc.* The currents of the epilimnion are no less important to the Unionidae in that a constant renewal of the food supply is effected. That it is entirely sufficient is shown by the fact that freshly collected mussels are never without plankton in the intestine, or without a crystalline style. (Allen, '14, and '21.)

Evermann and Clark ('17) have stated as a foregone conclusion that rivers are the abode of mussels *par excellence.* And it is true that there are more species and larger individuals. But I cannot wholly agree with their explanation. They say it is due to the changing water of the current, abundance of food and dissolved oxygen. Yet it is not explained why lake beaches are inferior in these respects to river shoals. In the former we have a slower, though no less steady, movement of water. The dissolved oxygen exists in great concentration, even to supersaturation. The plankton content of a lake surface is far in excess of that of most rivers. The average temperature of the lake habitats through the year is probably higher than in rivers, due to temperature discontinuity. Since these things are true, the metabolic

rate should be higher. Then, with higher metabolism, more food, and more oxygen, lake mussels should be the larger, if these were the determining factors. In the upper reaches of lake-fed rivers the mussels may profit to a certain extent by the water flowing from the lakes above.

It is likely that the Najades originally populated the fresh waters through the rivers rather than originating in the lakes. The lakes are younger, more transient, less extensive, at greater altitudes, and at the extremes of the drainage systems, and mussels have had less time in which to grow adjusted to them than to rivers.

Feeding Conditions upon Stream Deltas. Northwesterly winds have diverted the mouth of Pocahontas Creek southward into a shallow bay. The bivalve population of this bay were observed at times to have an almost complete change of diet. Ordinarily the food is lake plankton. After heavy rainfall the increased volume of creek water usually spreads out in a sheet of a few inches depth over the entire bottom of the bay. On such occasions the food of the mussels is greatly altered. The same phenomenon was sometimes observed to take place when there had been no rainfall, and at first it was puzzling to explain the sudden changes of diet from lake to stream plankton. The explanation turned out to be simple, when it was found to correspond to the diurnal or cyclonic temperature changes. The creek is shallow and its temperature changes more rapidly than that of the lake. After a cold period, its cooler water sinks into the water of the lake and spreads out in a thin layer at the bottom of the embayment. Its planktonts become the food of the mussels there, and they are excluded from their normal food supply. When the creek water is turbid and cold at the same time, it may easily be seen to underlie the warmer clearer lake water. It follows the bottom closely until the edge of the terrace is reached, where it spreads out horizontally in the region of the thermocline, in water of virtually equal temperature.

This alternation in temperature and food does not show evidence of inciting movement. But, during freshets, when the lake level is greatly changed upon the littoral, movements shoreward begin, due to pressure change.

In streams one may often see the siphonal regions of living shells used as holdfasts by such filamentous stream algae as Cladophora. This does not ordinarily occur in the lake. Yet it is a common observation in the above-mentioned bay where the water of the creek lies next to the substratum, even well out from the mouth of the creek.

Evermann and Clark acknowledge the greater food content of lakes. They suggest that fertilization is favored in the current of rivers and take no cognizance of the movements of lake water which accomplish the same purpose. Their explanation of the distribution of mussels upon riffles and other parts of a river bed lays emphasis upon the current as the distributional factor. Since lake species tend also to seek out gravelly or sandy beds and few choose soft bottom, the correspondence to river forms is exact. In lakes it is certainly the character of the bottom which is of most importance, and this factor can as readily explain distribution on river bottom. The current has of course produced the form of the bottom, and is thus an indirect factor.

These authors point to the possible reduction of vitality in small lakes through inbreeding—hence less size. They also show that a given lake species reaches its maximum growth only in the more fluviatile lakes. The writer has often noted this inequality between the mussels of the isolated, headwater lakes such as Winona and those of the elongated, fluviatile Oswego and Tippecanoe lakes.

Mussels are by no means unique in the occurrence of the smaller members of a family in smaller bodies of water, the larger members grading in size with the size of the stream or lake. Fishes are notable in this regard.

Movements and Migrations.

Isely ('13) through the checking up of marked mussels arrived at the conclusion that well-grown river forms are virtually sedentary. Evermann and Clark ('17) have often observed the tracks of mussels moving in shallow water. They state that the fixed habit increases with the increase in age and with increased depth. These observations are doubtless true in spite of the seemingly anomalous fact that younger individuals burrow more deeply than the older. The limey crust on the former rarely covers more than the siphon region of the shell, indicating the extent of submergence.

As told above, the writer has checked the movements of Winona Lake species, and finds an inshore or offshore movement corresponding to the stage of the lake water.

Observations on White River in late spring, and after summer freshets, show that sand bars newly exposed after having been submerged for a time, are more or less populated. Furthermore, mussels are stranded sometimes by receding water, and often tracks are seen which show that an effort has been made to reach deeper water.

Mussels upon rather permanent gravelly bars bounded by rock or mud bottom, are much limited in their movements. Shifting channels and shifting sand bars imply a corresponding movement of their population.

During the summer of 1915 the writer marked sixty or more *Lampsilis luteolus*, somewhat after Isely's method, and planted them at several points in the lake. Still others were planted during the following summer. Forty were put in water of three and one-half feet depth in Boys' City Bay, on bottom of marly sand. In the summers of 1916, 1917, 1919, and 1921 systematic efforts to recover these mussels were made. Many others of similar size were found, and many empty shells, but no marked mussels or shells were ever picked up. Others were put out in front of the Biological Station. Only two of these were found subsequently. Three years later one was found that had moved fifty feet from the starting point and had shifted from water of two feet depth to four. The other record was about the same in distance without change in depth, in six years. In six years the latter had increased in length scarcely one-fourth inch.

From the above it is clear that movements do take place. In some cases they are more or less seasonal, and of considerable magnitude deserving to be called migrations.

"Sunken Island" (Fig. 1) consists of several acres at 4-10 feet below the surface, having a sand-marl bottom, and only small areas not covered with Potamogeton. Little evidence of movement of its abundant mussel population is ever seen.

Mussels changed from one habitat to another usually exhibited greater unrest than undisturbed ones. A number were first accustomed to stream conditions, then subjected to the following experiment. They were placed, ten together in a rectangle, two siphoning upstream, two down, and the remaining six transversely to the current, in the mouths of Sugar and Pocahontas creeks. On succeeding days their positions were checked, with especial reference to tropic movements in response to current, depth, obstacles, distance moved, etc. The experiment was repeated many times.

There were 101 identifiable reactions considered, as follows, in those cases in which some movement had occurred:

(1) Remained transverse to current	25 out of 72 possible
(2) Turned transversely to current	5 out of 48 possible
(3) Remained faced downstream, siphoning up	23 out of 24 possible
(4) Turned downstream, to siphon up	23 out of 96 possible
(5) Remained facing upstream, siphoning down	13 out of 24 possible
(6) Turned upstream to siphon down	12 out of 96 possible

There was some tendency to remain transverse to the stream when placed that way originally, but much less tendency to assume a new position in opposition to current. There was a greater tendency to remain siphoning downstream than to turn that way. Of those set to siphon upstream nearly all retained that orientation, and one-fourth of the others assumed it, a much higher proportion than of those which chose to siphon in any other direction. This seems to bear out the tradition that mussels prefer to siphon upstream. Yet I am encouraged to believe that the orientation is as much a reaction to the pressure sense and a desire to reach deeper water, as it is a rheotropic reaction. Almost all the cases under item six took place after rains when the creeks rose; the depth of the water was doubled and the velocity increased. The reaction was more probably due to increased depth than to current. These cases are few but selected, and there were many rejected cases that seemed to point the same way. Yet an *Anodonta* placed in an eddy pool three feet deep did not move until a freshet raised the creek. Then it moved round and round the pool at the same depth, against the current of the eddy, not attempting to get out, and doubtless oriented by the eddy.

The bottom of Sugar Creek consists of much finer sand, gravel, and mud than Pocahontas. Hence the movements of *Lampsilis* were much more frequent and pronounced in the former. This despite the fact that Sugar Creek is cleaner and colder.

Movements were observed also in the outlet of the lake—Walnut Creek. When the dam was raised and the creek lowered most of its mussels sought deeper water, and more or less downstream movement took place. After periods of higher water the direction of movement was more random. Here again the amount of movement was coextensive with the favored bottom.

Obstacles on the bottom divert a mussel from its course. In the lake or in slight current the original course is often not resumed; but in a brisk current the mussel tends to fall back into the same angle with the flow of water regardless of what that angle may have been. Obstacles may include an alternation of sand, gravel, and mud. Driftwood, plant roots, rubble, or stones are the more obvious ones. The concave walls of an aquarium may be followed a little way, but will soon bring the mussel to a halt. Ripple marks upon sandy bottom may be seen to have diverted a mussel more or less shoreward.

The prevalence of mussels upon favored type of bottom is in itself an argument for greater or less migration. Juveniles do not remain where left by their fish hosts at random, but find their way to suitable substratum.

Besides the common lake species there occurred in the outlet not far below the dam the following additional: *Symphynota costata, Quadrula undulata,* and *Lampsilis anodontoides.* *Quadrula plicata* doubtless occurs; it has been mentioned that one individual has been taken in the lake.

Miscellaneous Observations.

In addition to the production of a shell the Unionidae may constitute a geological agent of a sort not usually recognized. The total amount of water siphoned and the amount of material taken out of suspension are surprising. Both mud and organic matter are separated out and precipitated in mucous clots. An aquarium jar filled with muddy water is cleared entirely in the course of a few hours by a single mussel.

Beneath the posterior end of a mussel which is actively siphoning in a lake the ground may be seen to be carpeted with a conspicuous amber-green slimy coating.

Due to the considerable deposition of marl on the plant grown terrace, through the reduction of the bicarbonates to carbonates in photosynthesis, there is much less lime present in the water of the outlet of Winona Lake. Prof. Scott has determined the carbonate ratio to be about thus: Springs : upper lake : outlet :: 3 : 2 : 1.

The writer compared the total weights and shell weights of 16 *Lampsilis luteolus* from Dickey's Point in the lake with an equal number from Walnut Creek. The results follow:

	From lake	From outlet
Average length	90.8 mm.	87.4 mm.
Average weight	127.0 gm.	107.0 gm.
Average shell weight	69.0 gm.	51.0 gm.
Ratio shell to total weight	54.0%	48.0%

The lake specimens were heavily encrusted with the usual marl deposit, and were cleaned for comparison. The total weights were then taken with the mantle chambers full of water. The number used was small, hence subject to error. The matter will be followed further. So far as the present data go we have a significant difference due to either the lime content of the lake, or to some other factor. This difference in shell weight amounts to six per cent of the total weight of the body, or about twelve per cent of the shell weight itself. Comparative data are not yet available from lakes of greater or less hardness.

SUMMARY.

Headlee and Simonton's survey of Winona Lake, Evermann and Clark's of Maxinkuckee, and Baker's of Oneida show great similarity in the mussel distribution. The first named authors ascribe the limitation of mussel beds in their narrow shore zone to the encroachment of enemies, to wave action, and to the character of the bottom. The writer finds that enemies are of less importance in Winona Lake than formerly, yet the shoreward distribution continues to be held within bounds, that wave action is pertinent chiefly as a stimulus to movement, and that the character of the bottom is probably the most important of all distributional factors.

The present writer agrees with Headlee and Simonton in disregarding sex as a distributional factor, and to some extent age. Pressure incited certain more or less seasonal movements, and light is a stimulus to movement.

Since the time of the foregoing paper on Winona Lake, much has been learned concerning the physical and chemical conditions of that body, the work chiefly of Scott. While the stimuli mentioned are largely responsible for confining the lake mussels to their narrow zone, yet the deeper parts of the lake are much less habitable to freshwater mussels for reasons which were necessarily disregarded in 1903. Due to the thermocline the conditions of temperature and dissolved gases are both unfavorable to mussel life. Furthermore the food supply is principally confined to the epilimnion, which bathes the lake bottom only along the shore.

A set of experiments show that the movements in creeks of mussels transplanted from the lake are due both to pressure and to current, the latter chiefly directive.

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A Study of the Life History and Productivity of Hyalella Knickerbokeri Bate.[1]

Dona Gaylor.

Introduction.

My first work with the arthrostracan crustacean, Hyalella knickerbokeri Bate was in the summer of 1920 at the Indiana University Biological Station at Winona Lake, Indiana, and its study was continued throughout the winter of 1920-1921.

The first problem was to determine, if possible, the contribution made by Hyalella knickerbokeri Bate to the food of higher animals. I soon found I could not get very far in my studies until I had worked out the life cycle of the amphipod in some detail.

Hyalella knickerbokeri is widely distributed. It is found in every state but at widely scattered localities. It is especially abundant in southern Canada, southern Minnesota, northern Iowa, Illinois, and Indiana. Miss Weckel ('11) extends its range to Lake Titicaca, Peru, South America. Its distribution is also discussed by Jackson ('12), Weckel ('07), and Della Valle ('93).

Methods.

Hyalella can be collected easily by washing Chara or other water plants in water contained in a small basin. They were then transferred to other vessels. The moving of individuals was done entirely with a small pipette and when the young were extruded they were transferred to a separate dish from that in which the mother was located, one at a time. It was next to impossible to count them when all together in one dish with the mother, due to the continual movement of all of them. Paired individuals were kept in separate dishes where they could be examined at will. The dishes were numbered and the data for each

[1] Contribution from the Zoölogical Laboratory of Indiana University No. 187.

pair entered under the same number in my notes as was written upon the dish.

I found that Hyalella would feed upon almost any water plant, but seemed to show a preference for certain ones such as Ceratophyllum, Elodea, and Chara. I also observed amphipods of the species feeding upon certain animal tissue, e.g. a dead dragon-fly nymph, a dead isopod, a dead amphipod, etc. Foods of other species of amphipods are discussed in some detail, by Sexton and Mathews ('13), M. Armand Virè ('03), and Della Valle ('93).

Relation of Reproduction to Season.

All the evidence that I have collected points to the fact that Hyalella has a distinct breeding period, limited to the warmer months. For example, when a hundred or so animals were examined during the first of February, not a single female was found with eggs in the brood pouch nor were there any young, present. The same was true when several hundred adults were examined the first of April. At neither time were any individuals observed mating when they were brought to the laboratory, but the second day after they were collected and in a warm room some fifty-odd pairs were isolated, the male carrying the female in the usual manner when preparing for copulation. These animals were collected on April 6, and on April 8 were noticed pairing. This sudden change in so many animals shows conclusively that both sexes were ripe and ready for mating as soon as conditions (which I believe to be temperature) were suitable, but the time for mating was put off as long as conditions were not favorable. All the females, whether mated or not, could be easily distinguished from the males, because the ova could be distinctly seen and approximately counted as they lay in the ovary which is located in the dorsal thoracic region. The testes appeared as a lighter green than the ovaries and are located approximately in the same position in the male as the ovaries are located in the female. The testes, however, were much more elongated, tapering at each end while the ovaries appeared as a cylindrical green patch ending abruptly at each end. The male ducts according to Kunkel ('18) open by papillae on the ventral side of the last thoracic segment. The oviducts each open at the base of the fifth coxal plate so that when the eggs are deposited they are caught in the marsupium which is formed by certain hair-like projections on the ventral side known as oostegites.

Fifty pairs were isolated the day the male began to carry the female. Of these I succeeded in carrying only three pairs through to the second oviposition. These were pairs 6, 9, and IV, Table 1. In two cases there were twenty-four days and in one case twenty-six days between two successive ovipositions. The dates are found in Table 1.

The young (Table 2) hatch about the twenty-first or twenty-second day after oviposition and remain in the brood pouch from 0-3 days when they are extruded at the time the moult of the female occurs in preparation for the next oviposition. The male may begin to carry the female as early as the seventh day before she moults, three or four days before the young are even hatched. The eggs become easily visible about a week before they are laid. Jackson ('12) succeeded in

carrying one individual through until the young were hatched. From the twentieth day until the twenty-fifth after ovipositoin he was compelled to be absent. On the twenty-fifth day the young were swimming about in the dish. Then, he says "From these observations we see that the eggs were in the pouch twenty-five days, at least, before they

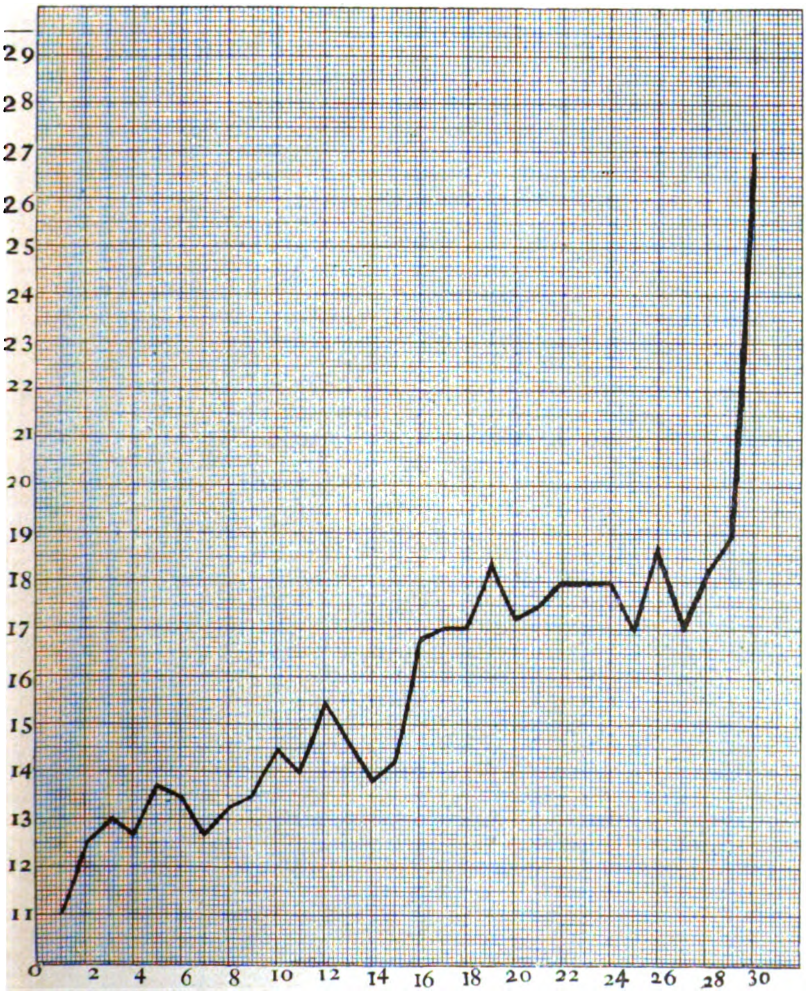

FIGURE 1

Figure 1. The ordinate represents the length of the third joint of the second antenna of the amphipod Hyalella knickerbokeri. The abscissa represents the number in a brood of the amphipods. There is shown a distinct correlation therefore between the age (since any part of an amphipod increases directly with age, the length of any part would represent the age) of an amphipod and the number in a brood.

hatched." I believe my observations and data show clearly that there is an incubation period of about twenty-one days with a brooding period of one to three days after hatching. The twenty-fourth day after the first moult the second oviposition takes place. Therefore, the young cannot be carried more than three days after they hatch for the female moults at that time.

The sequence of events in mating and oviposition is briefly stated as follows: The male carries the female about with him from one to seven days, leaving her when she moults and returning to carry her until

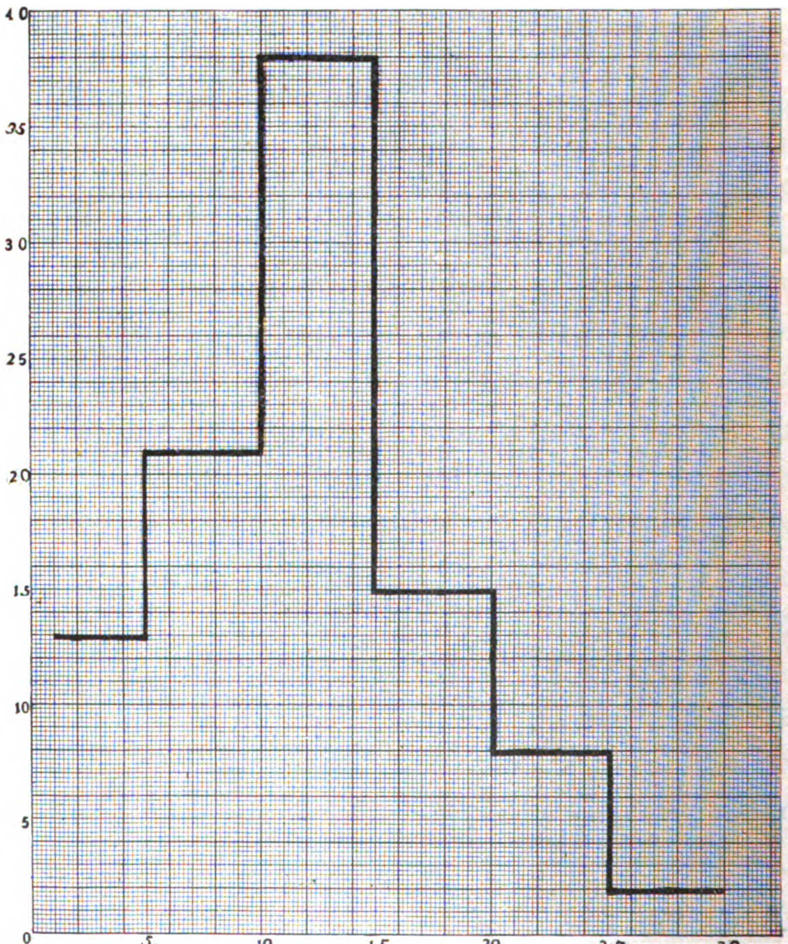

FIGURE 2.

Figure 2. The ordinate represents number of broods. The abscissa represents the number in a brood. This figure represents broods extruded between June 27 and August 14, 1920. Very few animals were breeding at the beginning of the observations recorded here.

copulation takes place which usually occurs during the next twenty-four hours after the female moults. Oviposition then follows copulation directly and the female breaks away from the male's grasp either before or during oviposition.

SEASONAL DISTRIBUTION OF NUMBER IN BROOD.

Preliminary measurements indicated that the third joint of the peduncle of the second antenna is in direct proportion to the length, which in turn has a direct correlation with the age of the animal. I

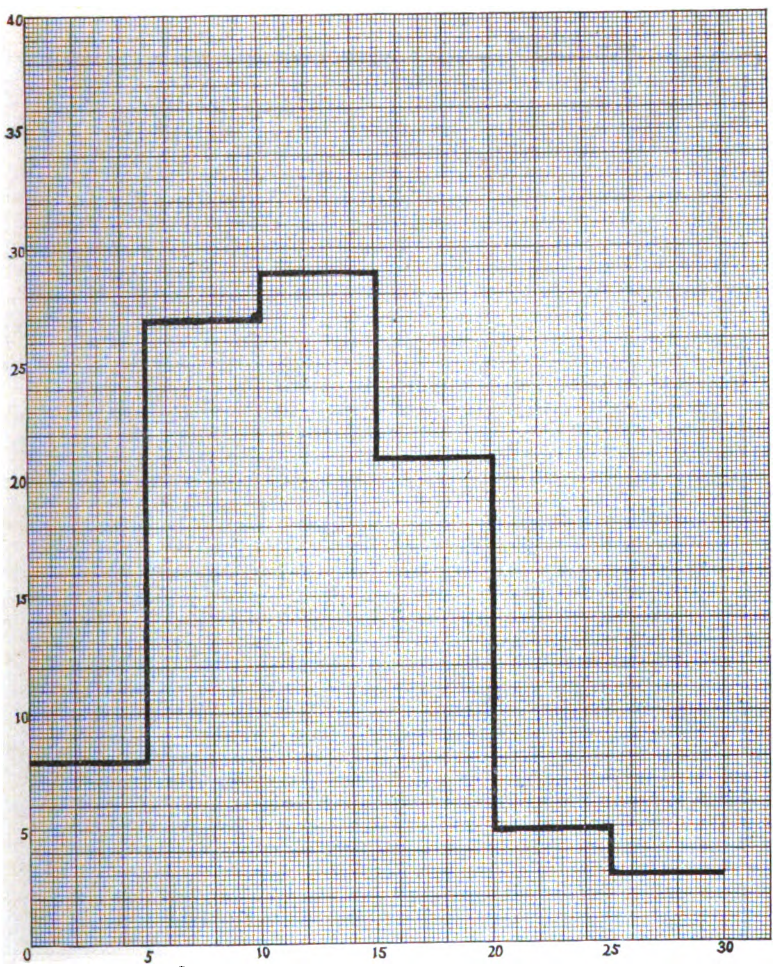

FIGURE 3.

Figure 3. Shows the transition period between time represented in Figure 1 and Figure 4. The time broods were extruded was August 7-14.

measured the aforesaid joints, taking the average length of the joint as the ordinate and the number in a brood as the abscissa, and constructed Figure 1. The figure showed that the number in a brood did increase with the length of the third joint of the peduncle of the second antenna. Therefore, I feel safe in concluding that the number in a brood increases with the age of an animal.

I have not had the good fortune to observe the number of young in two successive broods of the same female. However, Sexton and Mathews ('13) state that in Gammarus chevreuxi, the number of eggs seemed to increase with age, e.g., in the case of one individual the

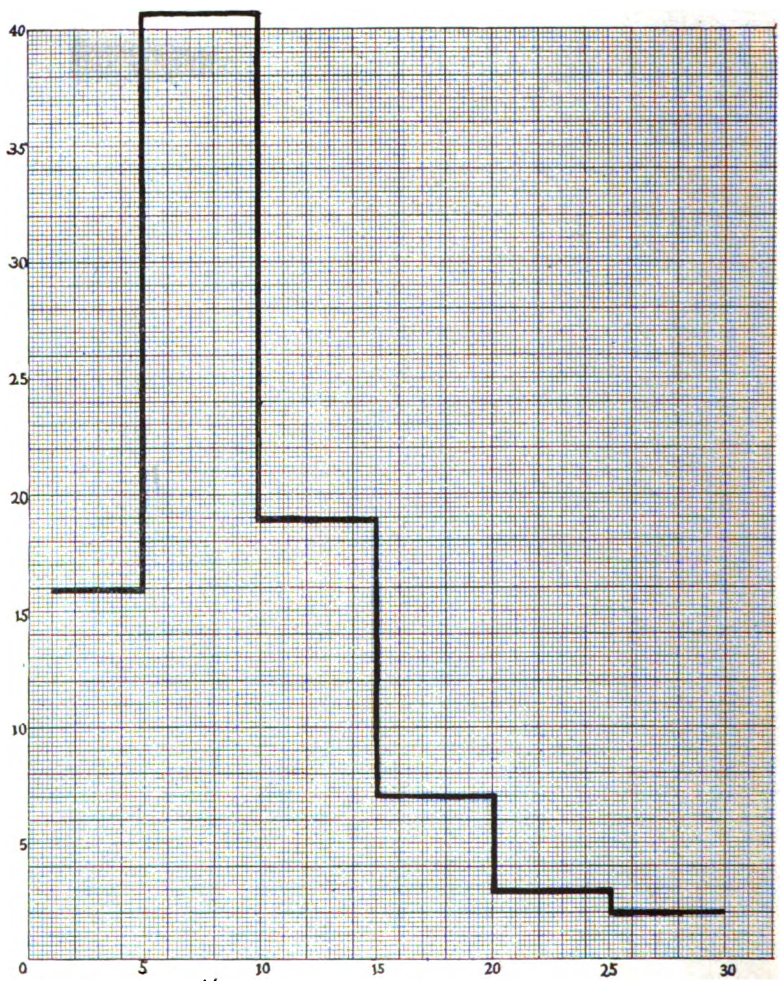

FIGURE 4.

Figure 4. Ordinate and abscissa same as in Figures 2 and 3. Broods extruded between August 16 and September 26.

number of eggs increased from eighteen to forty-four as the age of the animal increased.

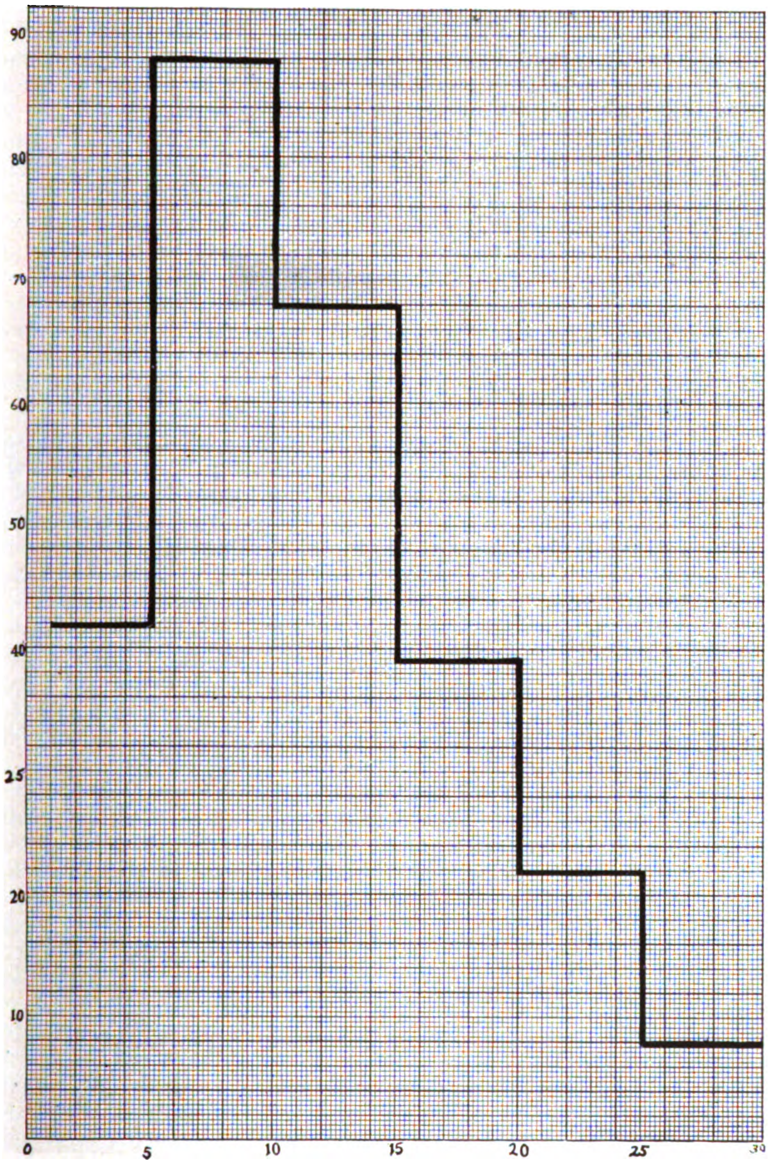

FIGURE 5.

Figure 5. Ordinate and abscissa same as in Figures 2, 3, and 4. Includes all broods extruded between June 27 and September 26, 1920, a total of 293 broods.

The largest number of broods with ten to twelve in a brood occurs early in the season during the last of June to the middle of August (Figure 2), but in the latter part of the season the largest number of broods with five to ten in them are found. (Figure 4.)

Let me suggest that probably the high point of (Figure 2), which represents all those females producing from ten to fifteen in a brood, represents those individuals breeding which were themselves produced the year before. As the season progresses the highest point is changed and the number of individuals producing five to ten reaches the largest number. There is a smaller number in a brood because younger animals are breeding and evidently they themselves were produced early that same season. Summing up then we might say that

1. In the early part of the season there are larger broods, produced as a rule, than during the latter part of the season, therefore

(a) Individuals reproducing in the first part of the season were themselves produced during the previous season and are older than,

(b) Individuals reproducing toward the last of the season which were themselves produced early that same season.

(c) Figure 3 shows the transition stage as occurring during the middle of August. That is, the largest number of broods produced with ten to fifteen in a brood is being reduced both in number and its relative position to the number of broods of five to ten in a brood.

After the females produce from ten to fifteen young in a brood the females seem to gradually die off. (Figure 5.) There could be very few reasons for this.

(a) The females might become barren after reaching a certain age but this is unusual in crustacea and I myself never found it to be true in the hundreds of individuals examined.

(b) Died when a certain age was reached, which is not true as there would be a sudden drop some place in Figure 5 but it is a gradual drop.

(c) The animals might meet with accidents such as being seized and eaten by other animals. This seems to me is the true explanation so that an animal increases in age it has fewer companions its own size and age. Thus an individual seldom, if ever, reaches a size, which in reality represents its age, to produce a brood above the thirty mark.

Additional Observations.

Holmes ('03) in his discussion of sex recognition among amphipods states that the instinct of the males for carrying the females is very strong, and that they cling to them by the first gnathopods even when injured. His point is that the lack of resistance on the part of the female when carried by the male, determines whether she shall be carried by him or not, and not merely her sex. In corroboration of this view I saw a male tugging away at a male who in turn was carrying a female. He pulled and tugged while the two ventral amphipods remained comparatively quiet. If the male carrying the female had not been carrying her, he would not have permitted the other male to carry him, but he clung to his mate in spite of his unusual position.

I had the good fortune to observe the process of copulation several times which was in detail as follows:

On April 15, 1921, I observed a male swimming about with a female which he held in the usual way, but every once in a while, when swimming he braced his pereopods against the dorsal side of the female and then by forcing them backward quickly, produced a short quick jerk of himself but did not seem to effect the female. This he did three or four times, which actions seemed to be a signal for copulation or at least a procedure gone through with before copulation which immediately followed and lasted a period of twenty-five or thirty seconds.

Without changing or releasing his hold of the female with his first gnathopods by which he held her on the dorsal side, he extended the posterior part of his body around the female to her ventral side until his uropods touched the marsupium of the female at its mid-ventral part. He pressed the marsupium with a succession of quick movements with the tips of his uropods, lasting as stated about some twenty-five or thirty seconds. His last thoracic somite just turned past the coxal plates of the female so that the ejected sperm could be quickly swept into the marsupium by the fast moving pereopods of the female. Meanwhile the male did not perceptibly move his pereopods. He next straightened himself into the dorsal position and swam off with the female, but modified the swimming by extending his first gnathopods with which he still clung to the female, pulled the female back as if he were shaking her. He did this several times and the whole process as described above was repeated as many as eleven times. The next morning, April 16, the eggs were deposited in the brood pouch and he no longer swam about with the female. One time I observed a pair copulating while the eggs were passing down the oviduct but usually, as far as I can observe, copulation occurs before the eggs even start down the oviduct.

On April 12, 1921, I observed a male carrying a female which had laid her first egg in the brood pouch. When the second one had passed down she struggled free and from that time 11:12 to 11:52 a. m., a total of forty minutes exactly, she had laid all the eggs. My observations for Hyalella knickerbokeri is the same as Sexton and Mathews ('13) for Gammarus chevreauxi as to the laying of the eggs, for the last one laid was the most posterior and also as they stated an oviduct was clearly seen. I could distinguish it only when the eggs were passing down it.

The ova are of a dark green color and as they left the ovary by means of this small tube, smaller in diameter then the ova, they were pressed out of their usual spherical shape. The eggs passed down both oviducts at the same time. The oviducts were seen to open at the base of the fifth coxal plate.

The incubation period for Hyalella knickerbokeri is, as stated above, about twenty-one days. The eggs remain green for a week or ten days, then turn black. When examined under the binoculars one can see the elongated embryos. About the eighteenth to the twentieth day they become a reddish brown or pinkish and on the twentieth day the red eyes of the embryo can be distinguished very well. Miss Langenbeck ('98) says that the colors of the embryos of Microdentopus gryllotalpa Costa changed color in a similar manner.

The young after hatching may be extruded that same day or any

time up to three days later when the mother moults in preparation for the next oviposition.

Hyalella knickerbokeri swims about restlessly until it comes in contact with any object and then crawls into the crevices and between the branches of plants until as much of it is in contact as possible. There it comes to rest. H. T. Jackson ('12) says of this species that, "They may come to rest curled up in the surface film, the surface tension then producing the contact stimulus." This may be easily observed at any time.

Phototropism.

The influence that light has upon Hyalella is quite noticeable. If a number are placed in a glass dish, they collect almost immediately on the side of the dish away from the windows. There are always some leaving the light and swimming to the other parts of the dish but they eventually get back to the side farthest from the light. C. H. Phipps ('15) says, the stimulus of the direction of rays to which the Amphipods react negatively has a stronger effect than the stimulus of light intensity." Thus we see Hyalellae are positively thigmotropic and negatively phototropic.

The average number of Amphipods in a brood is 11.27 out of a total of 3,103 young in 275 broods counted. The maximum number in any brood was thirty young and the largest number of broods occurred with seven in a brood.

Summary and Conclusions.

1. Data collected seems to point to the fact that Hyalellae of northern Indiana have a distinct breeding season during the warmer months of the year.
2. The breeding habits of Hyalella knickerbokeri are similar to other amphipods.
3. The female is carried by the male from one to seven days before copulation occurs.
4. The female moults before oviposition and the period between moults is twenty-four to twenty-six days.
5. Copulation lasts about twenty-five to thirty seconds but is repeated ten to twelve different times at intervals of a few minutes.
6. Oviposition follows copulation in the following twelve to twenty-four hours. There are twenty-four to twenty-six days between ovipositions, therefore there are twenty-four to twenty-six days between broods.
7. The incubation period is about twenty-one days.
8. The young are carried in the brood-pouch from one to three days. Then the female moults in preparation for her next oviposition.
9. Preliminary measurements indicated that the length of the third joint of the peduncle of the second antenna is in direct proportion to the life length.
10. The age of an amphipod is correlated directly with the number of young in a brood.
11. The number in a brood increases as the length of the third joint of the peduncle of the second antenna. (Figure 1.)

12. The number in a brood must increase each successive brood or as the animal increases in age.

13. Hyalellae probably live a second summer, for the largest number of broods occurring with ten to fifteen in a brood was toward the beginning of the season. (Figure 2.)

14. Hyalella knickerbokeri is positively thigmotropic and negatively phototropic.

15. The average number of young in a brood was 11.27 individuals.

16. The largest number of broods produced were produced with seven in a brood.

17. The maximum number in any brood counted was thirty young.

18. The total number of young counted was 3,103.

19. The total number of broods observed was 275.

Acknowledgment.

I undertook the studies recorded in this paper at the suggestion of Dr. Will Scott. It is due to his help that it is now completed.

State Normal School, Terre Haute, Indiana.

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TABLE I.

Number of Pair	Date ♂ began to carry W ♀	Date ♀ moulted	Date ♂ carried after moult of ♀	Date eggs were deposited	Date young were hatched	Date young were extruded	Date ♀ was again carried by ♂	Date of second moult	Date of 2nd time carried after moult	Date of second cviposition
Pair 1	April 8	April 9	?	April 10	May 1	May 1	April 24			
Pair 2	April 8	April 11	April 11	April 12	May 2 or 3	May 5				
Pair 3	April 8	April 9	April 9	April 10	May 2	May 4–7				
Pair 4	April 8	April 13	?	April 13	May ?	May 6				
Pair 5	April 8	April 10	?	April 11	April 3?	May 4 & 5				
Pair 6	April 8	April 10	?	April 10	May 1	May 4	April 29	May 5		May 6
Pair 7	Aptil 8	April 10	?	April 10	May 3–6	May 6				
Pair 8	April 8	April 9	?	April 9	April 30	May 1				
Pair 9	April 8	April 12	?	April 13	May 1	May 6	April 29	May 6	May 6	May 7
Pair 10	April 8	April 12	?	April 13	May 3					
Pair 11	April 8	April 13	?	April 13	?	May 4 & 5				
Pair 12	April 8	April 9	?	April 10						
Pair 13	April 8	April 12	April 12	April 13						
Pair 14	April 8	April 10	April 10	April 11						
Pair 15	April 8	April 13	?	April 13		May 6	April ..			
Pair I	April 7	April 8		April 9	April 29	April 29				
Pair II.	April 7	April 11		April 12	May 2					
Pair III.	April 7	April 10		April 11	May 2–3					
Pair IV.	April 7	April 8		April 9		April 30	April 27	May 2	May 2	May 3
Pair V.	April 7									
Pair VI.	April 7	April 9		April 10						
Pair VII.	April 7	April 10		April 11						
Pair VIII.	April 7	April 9								
Pair IX.	April 7	April 10		April 12						
Pair X.	April 7	April 13		April 13						
Pair XI.	April 7									
Pair XII.	April 7	April 9		April 9						
Pair XIII.	April 7	April 11		April 12	May 2					
Pair XIV.	April 7	April 10								
Pair XV.	April 7	April 11		April 11	May 2	May 4				

AN INDIANA INSECT SURVEY.

JOHN J. DAVIS.

The scientific and economic value of a survey of the insect fauna of Indiana and the need of such a survey has been emphasized to the writer for several years, so much so, in fact, that plans were drawn up three or four years ago, the initial steps being taken before I became connected with Purdue University. These plans, made before learning of the Biological Survey Committee of this Academy, seem to be appropriate at the present time and will, I believe, fit in conveniently with the plans of this committee.

Briefly, the object of such a survey would be to explore, exploit, record, map, collect and study the insect fauna of Indiana; to determine the occurrence and range of all insects of the state and to study their relation to plants, animals, human welfare, etc. Such a survey would include a study of the relation of insects to changing conditions, that is, swamp areas being reclaimed by drainage, peat bogs, sand areas, and the like, being put under cultivation for the first time, etc. It would also include studies of the small lake areas, caves, and similar places. In this connection it is planned to build up a working collection of insects representative of the state and of surrounding states and in time it is hoped that collections of insects, illustrating systematic, economic, biologic and ecologic groups, can be prepared for distribution to high schools and other public institutions.

No very definite method of procedure has been formulated. Indiana is very fortunate in having had a number of the country's best entomologists. Thomas Say, the father of American entomology, described and studied many species from Indiana during his residence at New Harmony, 1826 to 1834. One of the country's best known economic entomologists, Francis Marian Webster, carried on his early work in Indiana. The lasting influence of Webster's work on the agriculture of the state has been impressed upon the writer and more than one farmer of the older group has told me of the work which Webster did on his particular farm. More recent is the work of W. S. Blatchley and E. B. Williamson, both systematists without a peer. Blatchley's monumental works on the Classification of Coleoptera and Orthoptera are recognized standards as are also Williamson's equally classical Odonata studies. Besides Blatchley and Williamson, Indiana has other entomologists, nationally recognized as authorities in their groups, including H. F. Dietz and H. C. Kinsey, authorities on the Coccidae and Cynipidae, respectively, H. E. Enders and E. J. Kohl who have specialized on the biting lice (Mallophaga), W. H. Larrimer on the Jassidae, H. J. Painter on the Orthoptera, and the writer has studied the Scarabaeidae and Aphididae.

Necessarily an insect survey of this nature requires a division of work and it was planned to appoint honorary curators for the different groups or orders, to serve without pay, who would co-operate in col-

lecting, determining, monographing and in other ways assist in the plans. Where possible, residents of Indiana would be responsible for the work, but in some groups it would be necessary to look to others for co-operation in the systematic studies. Probably the Myriopoda and Arachnida should be included in the insect survey plans since they are usually treated with the insects and by entomologists.

Probably three card indexes should be maintained, as follows:

I. Index of the previous references in literature, arranged systematically.

II. Index of the collection records, (a) the insect index arranged systematically and (b) a host index referring to the species in the insect index (a); arranged alphabetically.

III. Index based on the economic, biologic, and ecologic records and arranged systematically.

All three indexes are in use by the writer at the present time and many records have been accumulated.

The uses and values of an insect survey for Indiana are innumerable but a few might be noted at this time.

Aside from the purely scientific value of such a survey and collection, this work will be of direct use in handling economic problems and in this connection we will enumerate as follows:

1. Prevents errors and facilitates accurate identification. We will not be safe from serious errors in our work with economic insects until we know far more of our insect fauna than we know now.

2. We will be able to define with considerable accuracy the "Life Zones". Thus the Insect Survey work will show the regions where watch must be kept or measures applied and will avoid waste of attention and effort in regions where the problem is not of importance.

3. In the case of sudden outbreaks of insects not previously known to be destructive, our Insect Survey will furnish data to enable immediate action and will furnish a basis upon which to proceed with our studies and for information to the public.

4. Insects are continually changing habits and where a previous knowledge of the insect has been available it has proven of greatest value in such cases. A few examples are: The strawberry root worm attacking strawberry plants but doing very little damage has, in the past few years, become one of the worst pests of roses in greenhouses; certain snout beetles of the genus *Lixus* which have heretofore been known to attack only wild dock are becoming a pest of corn in the swamp areas now being drained in Greene County; the greenhouse leaf roller was once only known to attack weeds but now is a common pest of celery and other garden vegetables as well as numerous greenhouse crops; the rose leaf-roller was little known when it attacked wild cherry but now it is a pest of rose; the quince curculio attacked only haws before the advant of the quince; a common tree hopper until recently was to be found only on wild plants but now it is generally common on several important ornamentals; and a host of other examples could be cited and additional ones are certain to come to us every year.

5. Biology teachers draw on the insects as an inexhaustible source for their classwork and the survey will undoubtedly become a valuable asset to the teaching of biology in the state. The educational value of a survey, such as planned, is beyond estimation.

A survey as planned is a gradual development but a start has been made and it is hoped this paper will stimulate the organization of an insect survey for Indiana. The insect collection at Purdue University is essentially a collection purchased from T. B. Ashton of Kansas some thirty years ago and is especially rich in Coleoptera, containing many rare and new species. The collection is being transferred from old wooden boxes to up-to-date Schmitt boxes and the various groups are being submitted to specialists for correct classification as rapidly as possible. The card indexes previously mentioned have already been started. The entomologists of the state have co-operated in furnishing specimens and data. An exceptionally fine set of Odonata has been placed in the collection by E. B. Williamson, many specimens of Coleoptera and Hemiptera have been furnished by Doctor Blatchley, a series of Crambidae have been donated by Geo. G. Ainslie of the U. S. Entomological Laboratory, Knoxville, Tenn., specimens of Jassidae by W. H. Larrimer, a valuable collection of Coccidae by Harry F. Dietz and the writer has included his own collection of Scarabaeidae and several thousand slides of Aphididae.

Thus a start at least has been made towards studying the insect fauna of Indiana and we wish to take this opportunity to urge all members of the Academy interested in the work to offer suggestions and to co-operate in making the Indiana Insect Survey the best in the United States.

Purdue University.

A National Insect Pest Survey and Its Relation to Indiana.

John J. Davis.

At the last annual meeting of the American Association of Economic Entomologists, it was recommended that a National Insect Pest Survey be organized under the direction of the Bureau of Entomology, U. S. Department of Agriculture, in co-operation with the official entomologists of the various states. Such a survey was intended to ascertain the extent of injuries caused by various insects, and their distribution, and to keep the entomologists throughout the country apprized of developments during the growing season, since such information would undoubtedly prove of greatest value in forecasting probable insect troubles, and would aid in the early recognition of recent insect introductions and newly established pests.

In response to the suggestion of the American Association of Economic Entomologists, Dr. L. O. Howard, Chief of the Federal Bureau of Entomology, organized an Insect Pest Survey under the direction of Mr. J. A. Hyslop. The objects of this survey as outlined by Dr. Howard include collecting and disseminating information on the status of insect pests throughout the country including both native and foreign pests; to give information on the first appearance of migratory pests so that possible precautionary methods can be taken; to accumulate information on fall and winter stages of such pests as a basis for forecasts; and to prepare reports and careful estimates of damage occasioned by insect pests.

The plan of organization involves for the Federal Bureau the general supervision of the work and issuing information in the form of monthly and special reports, as well as annual reports which will include a summary of seasonal geographic ecologic maps correlated with weather and abundance, tables of damage estimates, etc. A state collaborator or insect pest reporter has been designated for each state and he in turn works in co-operation with other entomological agencies of the state. The state collaborators are expected to submit reports to the Bureau of Entomology regularly each month so that the data are received at the Washingon office no later than the 20th of the month. The information received from all the states is then compiled and published the first of each month under the title of "The Insect Pest Survey Bulletin." The information needed for these reports includes name of insect, the crop or crops attacked, the seriousness of the infestation, whether or not it is wide spread or local, the per cent of damage, other pertinent facts regarding the situation, the success or value of controls which may have been put into practice and name of observer. The importance of this survey to the people of the State of Indiana cannot be overestimated. The entomologist by carefully studying these reports from month to month, is soon able to determine in a

general way the factor causing this or that insect outbreak; he is able to generalize and secure information which oftentimes is of greatest assistance in future years and above all he is able to follow the northern march of such serious migratory pests as the army worm and frequently to forecast the possibility of troubles which by timeliness and foresight may be easily overcome. The success of this pest survey is not with the Federal Bureau of Entomology nor is it dependent on the individual co-operation of the various state insect pest reporters, but upon the thorough co-operation of all entomological forces and others interested within the state. The speaker has been appointed state insect pest reporter for Indiana and takes this opportunity of requesting the co-operation of every member of this Academy in submitting information on all insect troubles.

During the past season we have had the earnest support of Mr. Harry F. Dietz of the State Conservation Commission. Any others in the state who care to co-operate in this work are requested to advise us. They will be furnished with data sheets and franked envelopes so that no expense in collecting or sending in the information will be involved. *Purdue University.*

Reactions to Light and Photo-Receptors of Annelida.

Walter N. Hess.

As one surveys the more important groups of Annelida, he at once discovers that these groups differ considerably from one another in their possession of eyes or other cells which function as photo-receptors. Although this paper will refer briefly to *Nereis virens* as representative of the Polychaeta, and to *Glossiphonia parasitica,* one of the Hirudinea, it will be chiefly confined to a discussion of our common member of the Oligochaeta, *Lumbricus terrestris.*

Nereis virens, as is well known, possesses two pairs of eyes on its prostomium. If the worms of this species are exposed to lateral illumination, from either the right or left side, they react negatively and orientate readily in a negative direction. If the eyes of a normal specimen are removed from one side with a sharp scalpel it no longer reacts as before, but produces "circus movements" in that it turns chiefly away from the side possessing the functional eyes. With all four eyes removed no reactions to light are apparent. From these experiments we feel warranted in stating that the cells which function in photo-reception in *Nereis virens* are definitely localized, and are probably found nowhere else except in its four eyes.

Our common leeches, such as *Glossiphonia parasitica,* possess several paired segmental eyes which function as photo-receptors in a similar manner as the eyes of *Nereis.* Here the eyes are more numerous and are more widely distributed, however, than in *Nereis.*

Our common earthworm, *Lumbricus terrestris,* possesses no perceptible eyes, yet it responds readily to the effects of light stimulation. Normal worms of this species, when exposed to light of ordinary intensities readily move away from the source of illumination, and orientate very definitely in a negative direction. These same worms, which are negative to light of ordinary intensities, become positive, in keeping with their nocturnal habits, when the light is greatly diminished. If the brain of a normal earthworm is removed by a dorsal incision, or by the removal of the first three anterior segments, the worm no longer reacts negatively to ordinary illumination, but it becomes strongly positive, and if six, or even more of the anterior segments are removed, they are still positive. There is a brief period, however, of only a few seconds' duration when first exposed to light that these worms give negative reactions. In each case they quickly adapt themselves to the light and become positive. Similar results were obtained with *Allolobophora foetida* with as many as forty anterior segments removed. These results show that the brain of the earthworm is not necessary for reaction to light and orientation. They, however, indicate that earthworms are more sensitive to light when the brain and the photo-receptors at the anterior end are functional, than they are when these are not functional. This accounts for the fact that, while normal

worms are photo positive only in very weak light, specimens with the brain removed are positive in strong light.

The experiments referred to above also prove conclusively that the earthworm possesses cells which react to light, and that these cells are not limited in their distribution to the anterior end. In fact, experiments show that the worm is sensitive to light over its entire body, the anterior end being most sensitive, the posterior end next in sensitiveness and the middle region of the body least sensitive of all.

These, and other experiments which were performed, seem to indicate that the Annelids as a group are negative in their reactions and orientations to ordinary light; that those forms which possess definite eyes seem to have the cells which function as photo-receptors localized in these eyes, while those worms that do not have perceptible eyes possess cells which function as photo-receptors that may be distributed more or less over the entire body. Some of the annelids, at least, which are negative to ordinary illumination are positive to very weak light, and if the brain and the anterior photo-receptors are destroyed these worms also become positive to strong light.

DePauw University.

A High Fecundity Record for Drosophila Melanogaster.

Roscoe R. Hyde.

Three females of the species Drosophila melanogaster have been encountered in my experiments with this fly that have made exceptionally high egg laying records. This fly as I have previously shown lives on an average of about forty days and during this period the average female deposits about 500 eggs. The fecundity record by days of the three flies in question is given in table I. The females were mated and kept in separate bottles to which a small amount of well fermented banana was added. Each day the banana was removed and a new lot added. The banana served for food and also as a trap for the collection of eggs. The eggs were counted with the aid of a small hand lens and dissecting scope. In this way I have observed the egg laying capacities of hundreds of these flies and the three listed are so exceptional that their performance is here recorded.

Number 8, the most productive fly laid 2,184 eggs. She emerged from the puparium on November 28, 1912, and was mated on the following day. Her egg laying record begins December 1 and continues until

TABLE I.

Fecundity record of three exceptional females of Drosophila melanogaster.

Number of ♀	Dec. 1912			Jan. 1913			Feb. 1913		
	8	9	13	8	9	13	8	9	13
1	25	25	30	23	33	38	32	30	15
2	30	26	21	25	22	37	15	9	10
3	27	17	51	35	48	43	16	22	15
4	23	18	6	32	8	22	22	20	14
5	25	35	23	17	22	12	21	6	13
6	25	33	25	25	30	30	17	3	10
7	21	17	7	29	10	19	26	20	10
8	12	30	42	31	18	31	21	2	7
9	26	28	20	8	10	6	29	9	15
10	20	34	40	18	23	20	24	8	4
11	31	26	21	19	0	0	23	D	5
12	43	45	40	43	35	25	28		10
13	27	39	31	40	25	23	17		4
14	24	29	31	29	35	30	19		7
15	34	28	27	19	13	16	19		6
16	50	2	39	21	18	7	17		6
17	46	28	45	47	37	30	12		3
18	30	29	40	21	13	10	6		2
19	53	50	43	31	21	32	9		1
20	58	53	42	28	22	28	5		2
21	22	1	53	40	36	21	8		4
22	5	30	20	23	36	23	5		2
23	36	25	24	30	30	26	0		2
24	45	17	30	14	19	24	0		
25	25	35	35	27	8	9	0		
26	28	22	35	32	19	20	D		
27	30	10	28	41	21	24			
28	35	15	25	35	33	15			
29	27	18	36	24	16	18			
30	30	18	31	13	10	16			
31	60	30	39						
Total number of eggs laid							2,184	1,613	1,807

February 26, 1913, when she became very feeble and was accidentally killed.

Attention is called to the fact that this fly often produced her weight in eggs during the course of 24 hours, and throughout her life she averaged her own weight in eggs every two days. The calculations are based on the following data:

(1) Determination of the weight of the egg of Drosophila before and after drying. A number of eggs were carefully picked with a needle from a mass culture and weighed. They were dried at 37° C for four days and again weighed. The weights are recorded in table 2. The average weight of the egg before drying is 0.0180 milligrams and after drying 0.0111 milligrams.

TABLE II.

This table gives the weight in milligrams of eggs of Drosophila melanogaster, before and after drying.

1919	No. of eggs	Weight before drying	Weight after drying at 37° C for 4 days.
Dec.			
5	100	2.0	....
6	100	2.3	1.5
18	112	2.5	1.7
19	100	1.3	0.6
21	110	1.3	0.9
Total.....	522	9.4	4.7
Average weight......		0.0180	0.0111

(2) Determinations made for 204 newly emerged females gave an average weight before drying of 1.2436 milligrams, after drying at 37° C for five days the average weight per fly was 0.305 milligrams. The average weight of 128 newly emerged males, 1.0601 milligrams; after etherization and drying for five days at 37° C, their average weight was 0.300 milligrams. The flies of this species vary greatly in size, depending upon cultural conditions. The determinations are here made for animals of average size.

When one computes the total weight of the 2,184 eggs laid by female number 8 in terms of the average weights of eggs and females here found it is demonstrated that this fly laid 32 times her weight in eggs. If account is taken of the dry weight of the fly and the dry weight of the egg then she laid approximately 80 times her weight in eggs. This is a striking physiological performance.

The fecundity record is apparently not modified as a result of fertilization for the unfertilized female lays eggs regularly and in large numbers. However, when the flies are kept in large numbers in the same bottle the females do not lay as many eggs on the average as when kept separately, despite the fact that on the average a larger egg laying surface may be exposed for each fly in the crowded culture.

Johns Hopkins University.

Army Worm Control Through County Organization.*

W. H. Larrimer.

A very general outbreak of the true army worm, *Cirphis Unipuncta*, Haw., occurred throughout the Central United States during the late spring and early summer of 1919. Since the distribution and general facts concerning this outbreak have already been recorded, it is intended to select a typical county where the infestation was most severe and cite it as an example of complete control of this pest through the co-operation of county farm organization.

As a matter of convenience, Henry County, Indiana, will be taken as an example, though any one of a dozen or more equally infested sections might be selected. Here the army worms appeared suddenly, as is their custom, in the timothy, rye, and wheat fields throughout the whole northern portion of the county. Many farmers were immediately in trouble and as is their custom in such a case, they began to make life miserable for the County Agent who, in turn, sent out an S. O. S. to every possible source for information and assistance in combating the pest. In response thereto the writer arrived at Newcastle, the county seat, at 10 a. m., June 18. Very few welcomes can equal that accorded to a Bug Man by a county agent who is besieged by farmers, who in turn, are besieged by army worms.

A very hurried survey of the situation was made. Owing to many of the reports and superstitions regarding the habits of the pest, the whole population, both of county and towns was verging on a panic. The idea prevailed that the worms were traveling south from the north end of the county and were eating every green thing and that nothing could stop them until frost had put an end to their depredations. Many infested fields of grain had been burned on the supposition that this was the only way the worms could be destroyed. Many barrels of gasoline had been wasted in not only useless but destructive fires of this nature. Furrows had been plowed through the center of grain and hay fields as well as around them, for no particular reason other than to stop the supposed general southward march of the worms.

One farmer said that he singled out a worm and followed it while it traveled three miles in one night. A poor woman, with tears running down her cheeks, anxiously inquired if something could not be done to prevent the worms from entering her house and eating up her carpets. The mayor of one town, was reported to have prepared a proclamation, declaring stores and factories closed and requested that the entire population be released to join forces with the farmers in combating the pest.

A short trip through the infested section revealed the fact that there was nothing unusual about this outbreak. The most heavily infested fields were plainly indicated by a group of farmers engaged in

* Published by permission of Secretary of Agriculture.

digging trenches. Several groups of from fifty to one hundred of these men were assembled, and the facts regarding the habits of the pest were imparted and control measures recommended. The most remarkable and outstanding feature of the situation was the near-panic caused by the absolute lack of any reliable knowledge whatever concerning a pest with which practically every entomologist is familiar. After a hurried conference with the county agent, a definite plan of action was formulated. Obviously the first thing to be done was to allay the popular fear due to the exaggeration of the threatened danger, and next, to organize the community for a definite plan of control, based on methods known to be effective. The mayor was advised that his proclamation need not be published. When it came to organization, the county agent was in his element. Through the Secretary of the Farm Bureau, a general call was sent out asking for representatives from every township in the county. The line call was sounded on the country telephones and a whole line was given the information at once. Each township chairman designated the representatives for his township to report at the Court House immediately. As soon as they arrived, a mass meeting of several hundred farmers was held. Any available hall being too small to accommodate half the crowd, the writer stood on a large boulder in the Court House yard and looked down on a most painfully attentive audience. A few brief facts concerning the life history and habits of the pest were given, emphasis being put upon the fact that practically all of the worms would disappear into the ground in less than a week and that an army worm never traveled any great distance as a worm. Assurance was given that the control measures recommended, namely, the combination of dust furrows and poison bran mash, had been frequently demonstrated and found to be thoroughly effective. Instructions for the construction of the dust furrow barriers and the preparation and application of the bran mash were given in detail. The recommended dust furrow barrier is made as follows: Throw a furrow with a plow toward the oncoming worms. Dress up with a shovel the straight side, which is toward the protected crop, so that a small bank of loose soil or dust comes flush with the top of this straight side. At frequent intervals, say 12 to 15 feet, dig shallow post holes in the bottom of the furrows. The worms coming into the furrow, try again and again to climb out over the straight side. They can easily climb the hard straight side until they reach the loose soil or dust which gives way under them and back they fall. After several vain attempts they crawl along the furrows until they drop into the holes where they can be killed by oil, burning, or merely mashed with a suitable chunk of wood. If left to themselves, very few caterpillars either in the furrows or the post holes, survive the hot sunshine of the next day. The standard bran mash was recommended to be applied wherever the worms were present and the crop was such that they were capable of causing further injury.

As to organization, under the leadershp of their chairman, the farmers of each township were to work as a unit, concentrating their efforts on the worst infested farms first. In case a township in the more heavily infested portion of the county needed help, the chairman was

to report his needs to the county agent, who could then furnish assistance from a township where the infestation was light. The farmers went to work on this simple plan.

Very few additional furrows needed to be made since by connecting those that had already been made at random and shaping them into an effective barrier was all that was necessary. The crop most seriously endangered was corn and where a portion of the field was infested, it was separated from the uninfested portion by a furrow and the poison mash used in preventing further injury.

A trip through the infested sections about sundown showed groups of farmers busily at work on a definite plan. Confidence in their method of protection had now almost entirely replaced the excitement of the forenoon. Now and then a group could be observed very much interested in watching the worms in vain efforts to cross the dust furrow. They would breathlessly watch a poor worm laboriously climb the straight edge of the furrow and as it reached the loose soil at the top and fell sprawling back again, a whoop of glee would burst forth from the watchers. Late that night many a farmer went home to his first sleep in three days.

The next day each farmer repaired his furrows and eagerly examined the results of poison bran mash put out the night before. Favorable reports came in from everywhere. On one particular farm where the farmer made and applied the mash as directed, absolutely no further injury to his corn occurred, while a small area which his slightly skeptical mind caused him to leave as a check, was totally destroyed.

The county agent now had the situation well in hand and professional assistance was in demand elsewhere. His final report came a week later, and being quite typical, is quoted as follows: "All you said has come true."

U. S. Bureau of Entomology, West Lafayette, Indiana.

A Preliminary Report on Hog Lung-Worms.

George Zebrowski.

The work covered in this report comprised a series of experiments on the habits and life history of the common hog lung-worms, Metastrongylus apri and Metastrongylus brevivaginatus. This work is still being continued, and its object is three-fold: first, to determine the morphology and habits of these parasites; second, the life history; third, to discover if possible, some practical means of control. The first two points are mainly covered in this report. The third point, and parts of the life cycle are yet to be completed. These experiments are submitted at this time with the hope, that being largely original, they may prove of value to other workers in this field.

The above parasites are of common occurrence in the lungs of Indiana hogs. By different investigators, these same species have been reported from every country where hogs are kept, hence, there is little doubt as to their world-wide distribution. Until recently little work has been done with these worms, especially as regards their habits and life history. Belief is still current that they are of minor economic importance, due no doubt, to their small size and general prevalance. However, it was observed, in the examination of several hundred lungs, that the number and extent of pathogenic lesions varied directly with the number of these parasites present. The very consistent results in this respect, led to the inevitable conclusion that these parasites must be considered of much greater importance in swine economy, than has hitherto been the case.

In the literature on this subject many conflicting terms are used to designate these parasites. Thus Strongylus paradoxus, and Strongylus apri, are two of a number of synonyms for Metastrongylus apri. This form is also confused with another species of common occurrence, namely, Metastrongylus brevivaginatus. In Indiana hogs these species occur in approximately equal number. The chief characteristics by which they can be distinguished are the bursa and spicules of the males. In M. apri, the bursa is bilobate and each lobe is sustained by five costae. The two spicules are very long and slender, and each terminates in a single barb. In M. brevivaginatus, the bursa is less campanulate, and each spicule terminates in two hooks. These spicules are much shorter, averaging only 1.25 mm. in length. The body of this species is also longer and stouter than is the case in M. apri. In these experiments M. apri is chiefly considered, although, in general, such conclusions as are drawn can apply to both species.

The most recent classification ascribed to these parasites is the following:

1. Phylum; Nemathelminthes.
2. Class; Nematoda.
3. Family; Strongylidae.

4. Sub-family; Metastrongylidae.
5. Genus; Metastrongylus.
6. Species; M. apri.
7. M. brevivaginatus.

DESCRIPTION.

M. apri: Cylindrical, unsegmented worms; body long and slender; buccal capsule absent or slightly developed; mouth with six lips; dorsal and externodorsal rays slender, the other thick; postero-lateral ray reduced or absent; females often show a dark hair line throughout their length; cuticle transversely striate. Male: 12 to 17 mm., average length, 16 mm.; spicules very long (about 4 mm.), and each terminates in a single barb; bursa deeply bilobate, opens laterally; five costae in each lobe; spicules segmented, cylindrical, capable of being coiled up within the bursa or of being withdrawn into the body cavity; dark brown, reticular tubes of chitin; fleshy portion consists of a membrane which is attached by a bulb like expansion to the seminal vesicle. Female: 2 to 4 cm.; vagina about 2 mm. in length; vulva close to anus, and on a slight eminence in front of it. Eggs contain living embryos coiled within them, and range in length from .05 mm. to .08 mm. The width averages .02 mm. less than the length; tail of female terminates in a short horn-like process; embryos when liberated measure .22 to .25 mm. in length, and .01 to .012 mm. in thickness.

M. brevivaginatus: The same general description applies to this species as to M. apri. Male: 15 to 20 mm. long; spicules 1 to 1.5 mm. long; body and bursa larger, stouter and more conspicuous, than in preceding. Females: 3 to 5 cm. long; eggs .07 to .10 mm. long and .05 to .08 mm. wide; larvae somewhat larger than those of M. apri.

MORPHOLOGY.

When viewed under a low power objective, the structure of these parasites is found to be relatively simple. In both sexes there is a dark, well defined, digestive tract traversing the entire length of the individual. This tract communicates with the mouth by means of a muscular, conoid esophagus, and terminates in a ventral anus near the posterior end of the body. Worms that are full grown show the body cavity to be almost completely filled with enlarged and convoluted reproductive organs. These, together with the alimentary tract, so completely fill the body cavity that there remain only here and there small irregular spaces. In the female the oviduct becomes continuous with the uterus, a short distance behind the esophagus. It then pursues a course parallel to the intestine, until it terminates in the vulva on a slight prominence in front of the anus. The reproductive organs of the male consist likewise of a single tube. However, this tube is not bent upon itself, as is the case in the female, but is single and tapering, and constricts to form the testicles and the seminal vesicle. To the terminus of this last are attached the two spicules, which function in copulation. The body of the female terminates in a blunt horn-like projection, that of the male in a rather complicated, membranous, clasping apparatus. During copulation the male grasps the female with this structure, and impregnates her by inserting the spicules already men-

tioned, into any region of her body, so that they penetrate to the uterus. Here the sperms are discharged and fertilization takes place.

The females are viviparous and produce hundreds of young. Within the uterus the eggs may be found in all stages of development. This development becomes more and more complete as the eggs approach the oviduct, till finally, when this last is reached, full grown, active larvae may be seen coiled within the egg capsules. The eggs are oval in shape and possessed of at least two membranes. On the outside there is a thick envelope of a gelatinous nature, which is very sticky, and which adheres readily to whatever surface it touches. Around the body of the embryo there is another thin, protective membrane, within which the embryo may often be found intact, even after the removal of the outer gelatinous coat. The thin, transparent, membranes which surround these eggs, together with their ease of procurement, should make them ideal for the study of karyokineses, and kindred biological investigations.

The body wall of these parasites shows many peculiarities. Enclosing the body contents is a transversely striated, muscular layer, somewhat thickened at the two extremities. In the male, well defined, oblique striations occur in the region of the bursa. The costae which support the bursal membrane are projections of this same muscle layer. On the outside there are several layers of very thin cornein, which are transparent and easily permeable to gases and liquids. When an adult specimen is placed in distilled water, the following changes may be observed: In a few minutes the outer layer of cornein separates from the muscle layer in blister-like swellings all over the body. These blisters are very transparent and easily overlooked. When touched with a needle, they at once collapsed, showing that they are formed of a membrane which encloses a fluid of high osmotic pressure. As this interchange of liquids continues, the specimen grows tense and turgid, until it finally bursts open along the median ventral line. The body contents are then forcibly ejected by the contraction of the longitudinal muscle fibres in the body wall. The rupture thus begun continues throughout the whole length until the worm is entirely everted. In this condition the body wall looks like an undulated band or ribbon, and is shrunk to about one-fifth of its original length. Specimens prepared in this manner are easy to study as the internal organs suffer little injury. By this means the eggs are discharged in great abundance wherever suitable conditions are found.

The characteristics shown by these worms suggests at once that very exact environmental conditions are necessary for their development. In this phylum of parasitic roundworms, respiration is seemingly effected through the dermal surface, for the adults, at least, show very quick responses to density changes in surrounding liquids. Indeed, so delicate is this adjustment, that a specimen of Trichinella spiralis (which had been kept in strong formaldehyde solution for three years) exhibited very life-like movements, when placed into a drop of water. Other specimens, known to be dead, acted in like manner when the solution in which they were kept, was placed upon a slide, and allowed to evaporate. These experiments would tend to prove that the body wall plays an

important part in the metabolic functions of these parasites. This fact is important, because it may offer ultimately a means of control. For example, Kroening reports very favorable results in the treatment of sheep lung-worms, by injecting a 1 per cent solution of carbolic acid into the trachea. The ready absorption of volatile liquids or gases by these parasites, would offer a ready explanation for his results. Further experiments are, however, needed along this line, especially as regards administering, and the standardization of lethal doses of the antiseptics used.

Distribution.

Believing that a knowledge of the approximate frequency and distribution of these parasites would shed some light upon their life history, a systematic count was kept to determine these facts. Table 1 shows the range and distribution for an entire year. The degrees of infestation of the different lots of hogs examined, have been reduced to percentages, and from these last the accompanying chart was constructed. Turning now to the chart we see two points of rather light infestation. These are due to the fact that the hogs were all over a year old. These instances tend to uphold the results of other investi-

TABLE 1.

Prevalence of M. apri in Local Hogs.

Date Examined	Hogs Examined	Hogs Infected	% of Infestation
1920			
March 15	11	4	.363
March 16	31	12	.387
April 3	19	3	.157
April 10	37	17	.450
April 24	52	23	.442
May 4	28	4	.142
Sept. 13	62	48	.774
Sept. 20	47	34	.723
Sept. 27	45	35	.777
Oct. 4	32	24	.750
Oct. 18	39	28	.718
Oct. 25	29	21	.724
Nov. 1	25	17	.680
Nov. 8	62	44	.709
Nov. 22	53	38	.716
Nov. 29	45	32	.711
Dec. 6	42	29	.690
Dec. 13	28	18	.642
Dec. 20	35	21	.600
1921			
Jan. 3	43	27	.627
Jan. 10	19	10	.526
Jan. 17	30	17	.566
Jan. 31	27	15	.555
Feb. 14	42	17	.404
Feb. 21	57	26	.456
Feb. 28	74	28	.378
March 7	62	27	.435
March 14	83	32	.385
March 21	28	9	.350
March 28	35	10	.314
April 11	62	29	.467
April 18	60	24	.400
May 2	74	35	.472
May 16	50	22	.440

Total number of hogs examined: 1458.
Number of affected hogs: 780.
Average percent of affected hogs: .534.

gators, namely, that older hogs or pigs are more resistant to these worms. If we omit these digressions, our curve will then show a decided symmetry. March was found to be the month of least infection, and this is doubtless due to their getting rid of parasites during the winter months, and not acquiring subsequent infection. The dotted line represents a period during which no observations were made. Again, the maximum infestation is found to occur during the summer and fall months. The percent of affected hogs diminishes gradually during the winter months, until it again reaches the lowest level in March. In the succeeding months of April and May, a rather sharp rise may be noted, and this in a measure corresponds to the warm rainy weather of these two months. It would seem therefore, that

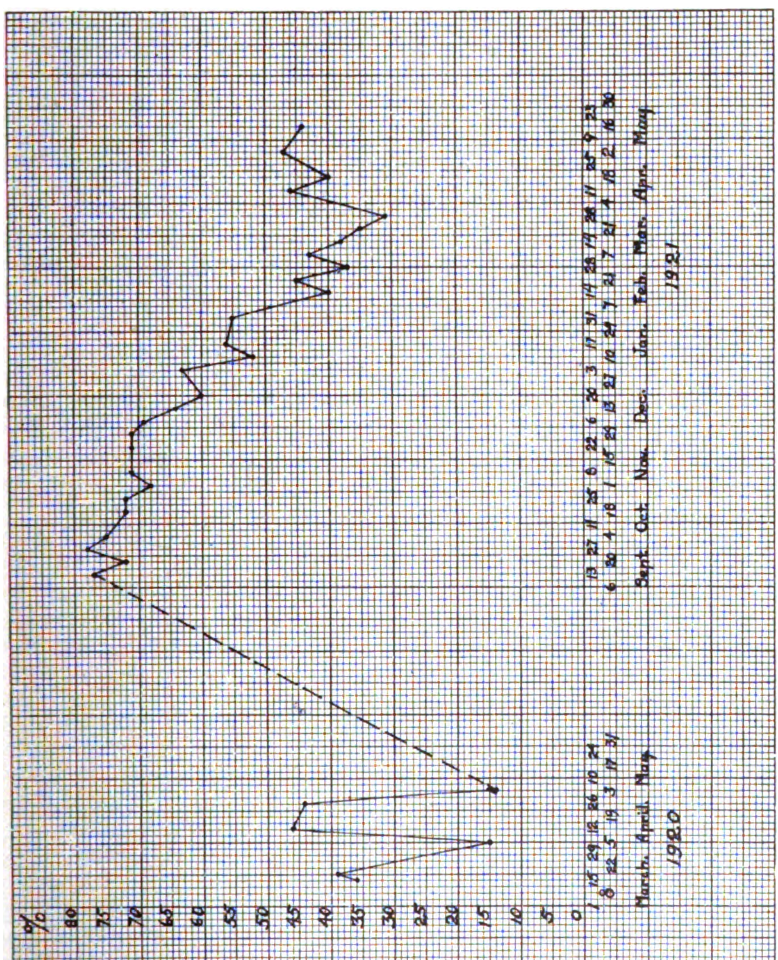


CHART FOR TABLE I.

warmth and moisture are essential environmental conditions for the development of these worms. The total number of hogs examined was 1,458. Of these 780 were found affected with lung-worms, which gives an average of 53 per cent for the entire year.

Frequency.

In this experiment, the lungs of four hogs were examined, which showed average infestation. These hogs are indicated respectively as A, B, C and D in table 2. In the lungs of hog A, three lesions were found; two in the right and one in the left lung. These lesions were carefully excised and dissected in physiological salt solution, in which the worms were counted. Like procedure was followed in the case of the other lesions, and the numerical results obtained are shown in the table. Certain facts that are thus brought out might be emphasized: first, the size of the lesion is but a rough index of the number of worms it contains; second, the right lungs are more often affected than are the corresponding left lungs; third, the ratio of males to females is approximately one-half.

TABLE 2.

Lung Worm Count in Affected Hogs.

Hog	Lung	Lesion	Size of Affected Area	Females	Males	% of Males
A	Right	1	31 X 17 mm.	18	10	.55
	"	2	35 X 18 mm.	62	22	.34
	Left	3	37 X 20 mm.	47	27	.57
B	"	4	40 X 35 mm.	32	18	.56
	Right	5	30 X 15 mm.	57	33	.56
C	"	6	35 X 22 mm.	28	17	.75
	Left	7	34 X 20 mm.	42	24	.56
D	"	8	27 X 15 mm.	51	20	.39
	Right	9	36 X 19 mm.	54	25	.46
	"	10	18 X 12 mm.	12	5	.41

Hog A contained 186 worms.
Hog B contained 140 worms.
Hog C contained 111 worms.
Hog D D contained 167 worms.
Average of males 51%.
In this count no attempt was made to separate the species of lung-worms.

Diagnostic Symptoms.

Unless they occur in very large number, lung-worms give little indication of their presence. The first symptom is a dry, husky cough, accompanied with an arching of the back. Frequently, there is a profuse discharge from the nostrils and eyes, and the membranes of these are pale. Young pigs that harbor this parasite show a general unthriftiness, anaemia, and looseness of the skin. In extreme cases, vomiting and diarrhoea may also occur. It should be borne in mind however, that all these symptoms are obscure and of too general application to be of much value. For example, a post-mortem examination of several pigs, that had evinced typical lung-worm symptoms, brought to light a heavy infestation of Ascaris suilla. These worms were present in such

numbers that they practically filled up the stomachs and intestines of all affected individuals. Superficial diagnosis should therefore be always followed by a post-mortem or microscopic examination.

The typical appearance of a lung affected with these parasites will show the initial lesions occurring at the very posterior tip. These lesions are gray in color, and have a solid appearance and feeling. A sharp demarkation also exists between the healthy and affected portions. These last rise prominently against the general surface, and are due to the clogging up of air tubes by the bodies of the worms and the debris they produce. Adult worms feed on blood and lymph by puncturing the walls of blood vessels, thus causing an acute inflammation. The eggs and larvae produce a diffuse pneumonia characterized by a dry puffiness of lung tissue. In old hogs, extensive, watery tumors occur, in which remnants of dead worms can be found. Small nodules, very characteristic of true tubercles, are also present.

One noticeable feature of these examinations was the common occurrence of bacterial lesions associated with the presence of these parasites. Probably these worms do not carry infection themselves, but the watery tumors which they produce undoubtedly make excellent culture media for any bacteria that chance to find their way into the lungs. In the hundreds of cases that were examined, secondary infections of this nature were of frequent occurrence. Lung-worms may thus be an important factor in causing disease.

Life History.

The general paucity of exact information in the field of parasitology is made very apparent when we attempt to find some concrete statements regarding the parasite in question. Until quite recently, nothing was known of its life history. The following report, copied from California Experiment Station circular 148, presents our most authentic knowledge of this subject.

"Early in our investigations we observed that the embryos found in the lungs were of two kinds. Our first thought was that these might be embryos of two different species of lung-worms, but this was discounted by the fact that we could find but one species of adults in the lungs. That the difference might be due to sex was rejected owing to the fact that the types differed not only in shape and structure, but also in their movements, location and habits. Thus the theory gained belief that these two types were designed to maintain a free-living and a parasitic generation. This belief was confirmed by Doctor von Linden of the University of Bonn, who found that in the mucus of the trachea and of the space behind the nose there were slim, strong-moving embryos that were capable of living outside the body. In the lungs the embryos were short, thick, slow moving and unable to live outside the body. Dr. von Linden found that if slim, strongly moving larvae are placed on moistened earth they continue their development, and she has been able to raise eleven successive free-living generations in this way.

"Dr. von Linden believes that the embryos destined to reproduce the free-living generations, work their way up to the trachea and are

swallowed and excreted from the body with the faeces. The embryos then moult and withdraw within their skins, which form a sort of cyst, protecting the larvae from extremes of heat or cold and dryness until conditions are suitable to their growth. Under favorable conditions the second generation of worms appears in from four to six weeks and further generations continue to appear at this interval for about four months. This period of increase is generally followed by a standstill of about three months when the increase again starts. The thick, slow moving embryos die almost immediately when placed outside the body."

In addition to repeating the above experiments two other alternatives were tried, namely, to determine the possibility of some intermediate host, and to see to what extent these parasites develop within the soil.

Theory of Free-living Generations.

The common occurrence and wide distribution of these worms suggests a comparatively simple life history. Before proceeding further, it might be well to emphasize the fact that much confusion still exists between these species of lung-worms. This difficulty is, however, more nominal than real, because even with the unaided eye both species of the males at least, can be readily distinguished. By plunging a mass of these worms into a 30 per cent solution of alcohol in a watch glass, and inspecting them against a black background, there is little difficulty in separating the two species. The males of M. apri are more transparent, more tightly coiled and slender, than is the case with M. brevivaginatus. The females of the former species are also more slender and average about 4 cm. in length. The following averages (obtained by measuring one hundred males of each species) give first the body length, and second, the length of spicules.

	M. apri.	M. brevivaginatus
Length of body	14.16 mm.	18.50 mm.
Lengths of spicules	3.80 mm.	1.25 mm.

An examination of twenty lesions from as many different hogs, showed the presence of both species of lung-worms in thirteen cases. Of the remaining seven lesions, five contained M. apri, and three contained only M. brevivaginatus. These results would indicate that this last species is much more common than is generally supposed. Experimental evidence seems to indicate that most females over 4 cm. in length, and the larger eggs (mentioned under description) belong to this species.

Attempts to duplicate the work of Dr. von Linden were in the main unsuccessful. Most of the points she mentioned were repeated, but the conclusions did not always coincide. The following tabulation gives the results obtained, together with their probable interpretation.

Structural differences were invariably found due to sex, especially if the larvae were well advanced in their development. This differentiation began to appear in the second week of growth when the larvae were grown in soil cultures. Besides this anatomical difference, a difference in size was commonly observed. These two distinct types could

always be traced to the presence of two species of lung-worms. If, for example, females over 4 cm. were placed in sterile soil, the resulting larvae were always of two kinds. The first was a slim, active form, and the other a rather stout, sluggish form. In this last, ovaries were clearly distinguished in the second week of growth. The larvae within each group were consistently alike, hence their structural differences could only be due to sex. In soil cultures where no effort was made to separate the females on the basis of length, two kinds of larvae were also found; namely, the slim, and the active forms. However, each of these types could be further divided into two groups, which were identical in every respect except size. The presence of these larger larvae could be best explained on the basis that they were the young of M. brevivaginatus.

Active larvae were found in scrapings from the sinuses of the head, the trachea, and in the mucous discharges from the nose. These more active forms were found to be due simply to differences in the stage of development. Experiments have shown that the larvae of lung-worms remain sluggish for several days after they are hatched, during which time important morphological changes occur.

Attempts to raise the free-living generations were unsuccessful. However, when the proper environmental conditions were provided, there was little difficulty in growing larvae taken directly from the lungs. Such larvae grew actively for a period of four weeks, after which time no growth took place but they continued to live indefinitely. These results do not agree with the statement made by Dr. von Linden and others, that the embryos taken from the lung die almost immediately when placed outside the body. It was found that young larvae are very susceptible to moisture and temperature changes, to bacteria and decomposition products, and to proper aerobic conditions. No difficulty was experienced in keeping lung-worm larvae for several days in physiological salt-solution, provided this solution was changed daily, and thoroughly aerated.

Theory of Intermediate Hosts.

In conducting this series of experiments, such animals were used as are commonly found in hog runs and wallows, and which might readily be a source of infection to the hog. Table 3 shows in tabular form the animals with which experiments were conducted and their attendant results.

Most of the flies and lice were caught upon the bodies of dead hogs. A count was kept of each species, to find if possible, the per cent of infected individuals. Specimens were examined by tearing them to pieces in salt solution, and dissecting the contents under a binocular microscope. No affected individuals were found.

Attempts to infect the Ostracoda and Cyclops were made by placing them in a beaker of water, into which were also put a large number of lung-worm larvae. These were left in contact for ten days, during which time daily examinations were made to determine any occurrence of parasitism. The results were consistently negative. Examination of these crustacea was facilitated by first dissolving out the

calcareous skeletons with HCL, and then compressing them between two slides.

Earthworms, from which most of the intestinal contents had been squeezed out, were placed into soil cultures containing larvae in different stages of development. These were examined at varying intervals, ranging from one to five weeks. The method of doing this was to place a cleaned individual into salt solution, in which it was cut open and the intestinal contents examined. Small pieces of the worm itself were next compressed between two slides and observed under the microscope. Among the contents of the intestine, many lung larvae and larval skins were found. However, the larvae were all dead and seemingly had undergone digestion. Parasitism of the worms themselves was found in two individuals. These showed, imbedded in the tissues, roundworms very similar to the lung-worm larvae in question. Remembering, however, that all were equally exposed to infection and that only these two specimens were found parasitized, any conclusions derived from this experiment must necessarily be unreliable. Such parasites as were found could have been acquired before the worms were placed into the soil cultures.

In conducting the experiments with rats, four individuals were used. Two of these were fed lesions containing lung-worms at intervals of one week apart for a period of four weeks. The other two rats were fed larvae in advanced stages of development, and at approximately the same intervals, for a period of ten weeks. After one month the first two rats were killed and found free from infection. The other pair of rats was killed three months after the first, and two weeks after the last feeding. These had very typical verminiferous lesions in both posterior lobes of the lungs. When these lesions were examined, numerous dead larvae and cast skins were found within them. No living larvae were found.

An examination of the rat faeces showed that most larvae were excreted within the first 24 hours. In faeces of the first pair of rats no larvae could be found after the second day of feeding. In the case of the other two rats, the larvae persisted for four days. A large portion of these last seemed to have escaped digestion, but no living larvae were found.

Blood samples of these rats were taken at different times, but gave negative results.

TABLE 3.

Experiments with Intermediate Hosts.

Species	Number Examined	Results	Completed
Colliphora erythrocephala (Blue-bottle Fly)	35	Negative	1920 Sept. 22
Musca domestica (Common House Fly)	67	"	Sept. 27
Haematopinus suis (Hog Louse)	47	"	Sept. 28
Cypris candida	19	"	Oct. 9
Cyclops	22	"	Oct. 11
Earthworms	17	?	Oct. 27
White Rats	4	Positive	May 9

It would appear from these experiments that M. apri and M. brevivaginatus have no intermediate hosts, but that active, growing larvae may occasionally invade the lungs of another animal than the hog. In such a case, however, they are unable to continue their development. An exception might be cited in the case of the human host; for several cases are on record where worms, seemingly identical with those of the hog, have been found in human lungs.

Theory of Partial Development in the Soil.

Analyzing the facts thus far considered, it would appear that these parasites spend a part of their development within the soil. To grow these worms, small wooden boxes were used parafined on both surfaces. Different kinds of soils were found to give different results. The optimum soil types were, first, a humus to which some sand had been added, and second, soil scrapings from the bottom of an old manure pile. Neutral or slightly alkaline soils gave the best results. It appears that young larvae feed within the soil, for they made no appreciable growth in the sterile plots until such time as seeds were planted and had begun to sprout. In this regard oats and beans gave satisfactory results, and they served moreover, as excellent indices in the control of moisture. Check experiments were in all cases conducted with soil sterilized under a pressure of fifteen pounds of steam for one hour.

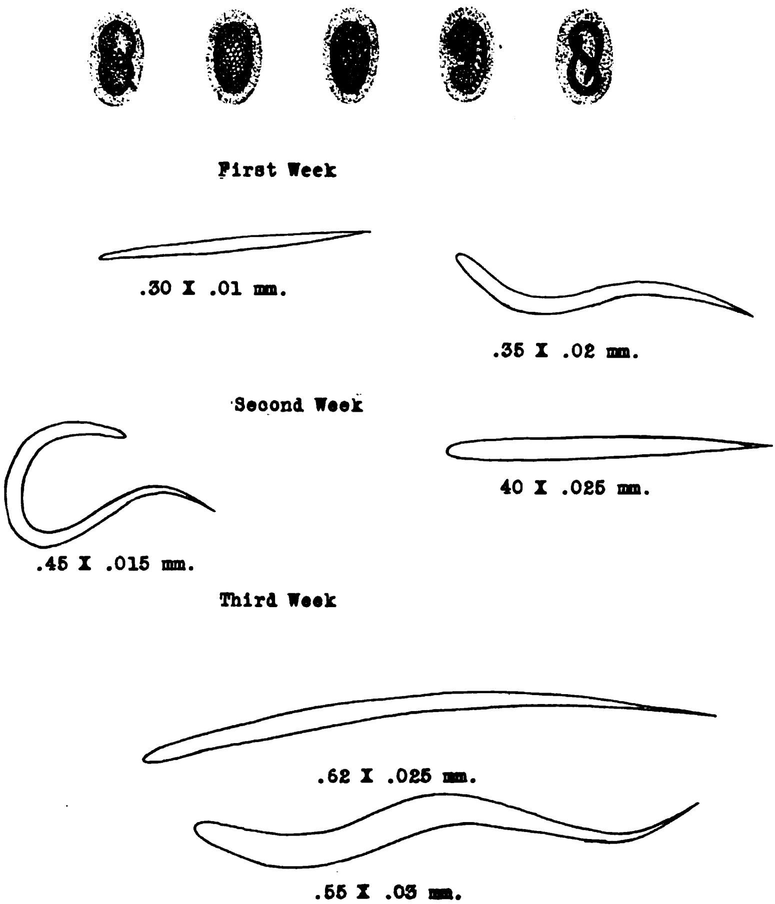
Besides the soil types mentioned above, moisture and temperature were found to be factors of prime importance. The temperatures that gave the best results and at which the larvae were the most active, ranged from 35 to 40 degrees Centigrade, and preferably within the upper limits of this range. The moisture requirement is peculiar and must be very exact. As these parasites require an abundance of oxygen, all experiments involving them had to take this factor into consideration. Too much and too little moisture were both detrimental. The former excluded the air from the soil, and the latter condition inhibited motion and proper metabolic development. The larvae grew most rapidly in soils that were damp and porous, and that contained much organic matter. Moisture requirements were best controlled by means of vegetation growing within the plots. Newly hatched larvae are especially succeptible to these changes, and they are readily killed if the soil is allowed to dry out.

In their development these larvae showed many marked peculiarities. Under ideal conditions they increased rapidly in size during a period of four weeks. During this time the digestive tract and sex organs become well defined. The bodies of both sexes terminate in a spine-like process, which is much longer in the males. These last are also more slender and active than the females. Motion is effected by side to side contractions of the body, which cause the worm to move rapidly along especially in a media of semi-fluid consistency. Plate I shows the appearance of these larvae during different stages of growth.

A decided metabolic difference exists between partly developed larvae and those which are just hatched. Experiments conducted with different digestive ferments, such as bile, saliva, liver extract, etc., showed that the former larvae are much more resistant to the action of

PLATE 1

DEVELOPMENT OF METASTRONGYLUS APRI



DEVELOPMENT OF METASTRONGYLUS APRI

The eggs are intended to show the various developmental stages.
The larvae show actual measurements, and were drawn by means of the camera lucida.

these enzymes. Thus, two-weeks-old larvae individuals were not digested when left in these ferments for 24 hours. On the other hand, young embryos were all killed after five hours, unless they were protected by the egg membranes. Likewise, when subject to weak antiseptics of different kinds, the same general results were obtained. Freezing seems to kill at all stages of development, but experiments with dessication have shown that two-weeks-old larvae can withstand prolonged drying out without injury. Such larvae were revived three months

TABLE 4.

To Show the Rate of Growth of Metastrongylus apri in Millimeters, Attained Within the Soil.

First Week		Second Week	
Length	Width	Length	Width
.32	.015	.42	.011
.33	.015	.46	.015
.30	.012	.40	.010
.35	.016	.48	.020
.31	.014	.49	.021
.30	.012	.50	.025
.29	.011	.42	.011
.32	.015	.48	.020
.32	.012	.39	.018
.35	.015	.52	.025
Third Week		**Fourth Week**	
Length	Width	Length	Width
.55	.020	.63	.028
.50	.018	.72	.037
.60	.035	.74	.054
.65	.040	.60	.035
.50	.018	.67	.025
.65	.035	.70	.035
.63	.035	.72	.045
.59	.020	.69	.035
.57	.018	.74	.055
.62	.032	.65	.040

The above measurements are random selections of male and female larvae of both species. They attained their maximum size by the end of the fourth week, after which they began to die off. However they continued to persist indefinitely.

after they had been permitted to dry out in the soil at room temperature, by placing them in water. Incidentally it was noticed that many samples of these same larvae continued to live after they had remained in weak chloral hydrate solution for three months. Evidently, profound morphological changes occur during this time, which enable these parasites to withstand unfavorable environmental conditions.

Six weeks after this period of rapid growth, the larvae still remained active, but did not increase in size. Numerous cast skins and dead larvae began to appear. It is certain that moulting took place, but the actual number of these moults could not be determined. Unfavorable conditions seem to prolong the life cycle of these parasites, for they encyst and remain inactive, until such time as favorable conditions return. Apparently these larvae die off gradually if they do not find a suitable host. In the laboratory, they have persisted in this manner for almost a year.

There are also good grounds for belief that these worms may develop directly within the lungs. Since, in a majority of cases, the initial lesion begins at the very posterior tip of the lung, and often contains great numbers of worms, the theory is hardly tenable that all these worms entered as individual larvae, and all migrated to this particular area of the lung. Most lesions that were examined, were found to contain these strongylus in all stages of development. The adult specimens lay massed together at the terminal end of a bronchus, while the more active larvae, equivalent in size to those which had

attained a week's growth within the soil, could be found in the mucous of the entire respiratory tract. Where two or more lesions occurred in a single lung, one was invariably found that was older than the rest. Such a typical old lesion was hard and watery to the touch, and when cut open, was found to contain numerous granules among which were the disintegrated bodies of adult worms. The suggestive thing is that a lesion of this kind always occurred at the lowest part of the lung, and the secondary lesions were scattered along branches of the same bronchus in which the older lesion was found. These conditions could be explained on the theory that the adult worms secrete toxic substances which cause an accumulation of lymph, that eventually kills them. The partly developed larvae, being active and resistant, make their way along the course of the bronchus until they lodge at the terminus of one of its branches. Here they begin to feed and grow, producing a new lesion light pink in color and of a dry, puffy nature. There seems to be no reason why sexual maturity could not be attained within the lung in this manner, and by this means the progeny of a single worm could infest an entire lung.

Modes of Infection.

The next question that suggests itself is, "How do these parasites gain ingress into the lungs?" Experimental proof is available to show that there are at least two methods. The rats already mentioned were given these larvae smeared on bread, in combination with which they were readily eaten. Most of these larvae subsequently passed out with the faeces, but apparently enough resisted the action of digestive ferments to find their way into the lungs, where they produced the characteristic lesions. Another experiment, conducted with three pigs to which these worms were fed in slop, gave very definite, positive results. These results are given in the appendix.

An additional mode of infection could be by inhaling the larvae as dust. For example, when the sweepings of a hog house, in which affected hogs were kept, were shaken up in a jar of water and allowed to stand over night, numerous, active larvae were found in the sediment, similar in all respects to those under discussion. The experiments on dessication further strengthen this theory, for, some of the larvae could be revived in fifteen minutes after they had undergone drying for a period of six days. The mucous of the nasal passages would be an excellent place for these dessicated parasites to lodge, and to continue their development.

Preventive Measures.

To effectively control these parasites prevention rather than cure must be the chief end in view. The common practice of continually raising hogs on the same piece of ground, can only result in a heavy infestation of the soil in all kinds of parasites. Changing the site of the hog lot every two or three years would certainly reduce this infection to a minimum. Experiments with the culture plots have shown that a heavy application of lime, is very effective in killing these parasites. In none of the plots which were subject to this treatment

could living worms be found after two weeks. Other writers recommend a top dressing of kainit for the same purpose. Liberal application of these substances to pastures and yards, is the best method that can be recommended at this time.

As infection is especially likely in young pigs clean bedding and quarters should be provided for them. Dr. R. A. Craig has found adult lung-worms in three-weeks-old pigs, which fact together with the ascaris infection already mentioned, would indicate that young pigs may be parasitized directly by eating worms which have been excreted by older hogs. Segregation of affected individuals, and the careful examination of newly purchased stock, for symptoms as coughing, arching of the back, etc., are additional factors that can be recommended.

Appendix.

This experiment is a summary of the pig-feeding tests already referred to. This data could not be incorporated into the main body of the report as the pigs were being used for another purpose at the time this experiment was conducted. Altogether six pigs were used, and were selected to approximate the same size and development. These were divided into two groups of three each, which for convenience will be designated as Group A and Group B.

Group A.

These three pigs were used as checks. No worms were fed them, and they were simply kept in a clean concrete pen so that the chance of infection would be reduced to a minimum. Due to the fact that all of these pigs were some three months of age before they were segregated and had ranged in an open hog lot during this time, absolute freedom from infection could not be achieved. Examination of the lungs of these pigs, killed at the same time as Group B, gave the following results:

Pig	Right Lung	Left Lung	Male Worms	Female Worms
1	1 lesion	none	3	5
2	1 lesion	none	2	7
3	1 lesion	none	4	9

Group B.

The pigs of this group were fed lung-worm larvae at two different times, namely, on March 24 and May 12, 1921. The larvae were of different ages (from one to five weeks), and had been grown in culture plots in the laboratory. The feeding of these worms was effected by

Pig	Right Lung	Left Lung	Male Worms	Female Worms
1	3 lesions	2 lesions	39	57
2	4 lesions	2 lesions	42	63
3	General verminiferous	bronchitis		

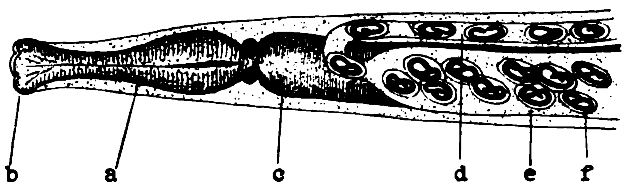
mixing them with grain in the form of a slop, and pouring this mixture into a trough. These pigs were killed on June first, of the same year, and the lungs, when examined were found to be badly infested. The following table shows the number of worms and lesions that were found.

The lungs of pig three were badly affected with these worms, although no localized lesions could be found. Partly developed worms were found in all of the bronchi of the lungs, which showed also a swollen, oedemic condition. The large number of males present in all of these lesions was a noticeable feature, and was doubtless due to some selective influence in the culture media.

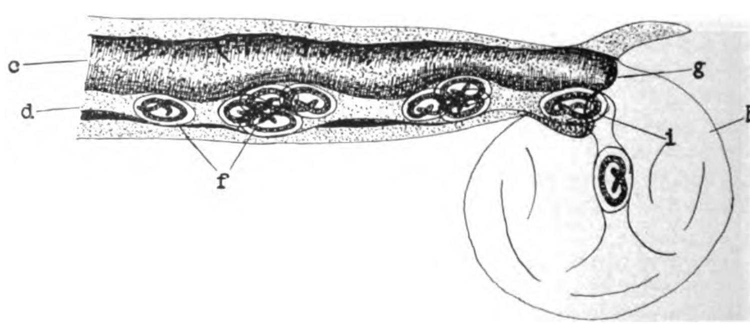
Although these experiments are not as conclusive as could be desired, they undoubtedly prove that partly developed larvae will infect hogs under favorable conditions. *Purdue University.*

PLATE II.

METASTRONGYLUS APRI **A**



B

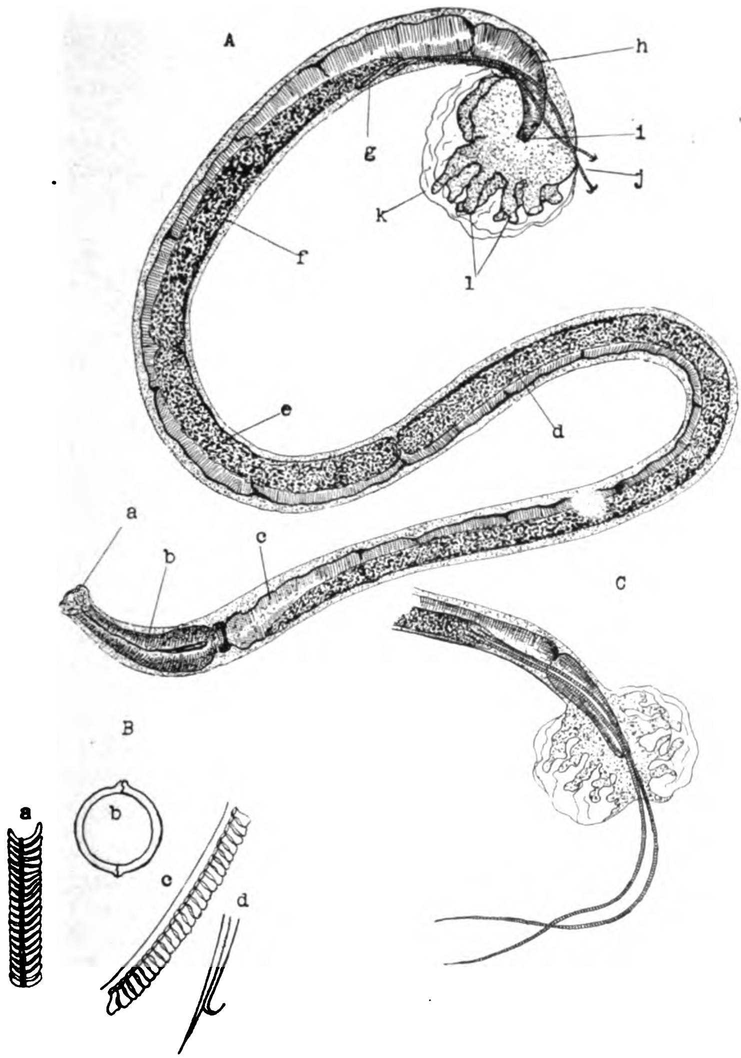


METASTRONGYLUS APRI.

A. Anterior view of female: a, esophagus; b. mouth with six lips; c. intestine; d. oviduct; e. uterus; f. eggs.

B. Posterior view of female: c. intestine; d. oviduct; f. eggs; g. anus; h. vulva; i. vagina.

PLATE III.
Metastrongylus Brevivaginatus.



METASTRONGYLUS BREVIVAGINATUS.

A. View of male: a, mouth with six lips; b, esophagus; c, intestine; d, e, testicles; f, seminal vesicle; g, anterior end of spicule; h, rectum; i, anus; j, spicules; k, bursa; l, costae.

B. Structure of spicule: a, top view; b. cross section; c, side view; d, end view.

C. M. apri, posterior view of male. Note comparative length of spicules.

Crop Rotation as Affecting Nitrate Production.

I. L. Baldwin, U. L. Coble and J. W. Chamberlain.

One of the great outstanding problems of the modern scientific farmer is that of maintaining and improving the soil fertility. It is in connection with this great problem that the science of Soil Bacteriology, the study of the habits and activities of the microbic flora of the soil and their relation to soil fertility and plant growth, has recently developed. Although investigations in this field have just begun, enough has been done to prove that such scientific studies are highly valuable in solving some of the problems relative to the question of soil fertility and plant growth.

As yet few scientific investigations have been reported on the effect of various crops and crop rotations on the nitrate content of the soil. As a result the following studies relative to the nitrate content and nitrifying power of the Rotation Plots of the Purdue Experiment Station Field No. 6 were undertaken.

A brief description of the plots and the experiment being conducted by the Purdue Station will be of value in interpreting the results of these studies.

The soil is a Sioux silt loam, containing some gravel and is underlaid by a gravel subsoil. The top soil is shallow, and just below at varying depths there is a hard layer somewhat similar to a hardpan. This soil dries quickly and packs easily. The organic matter content is fairly high.

The plots were laid out in 1889, as test plots one-tenth acre in size in strips fourteen feet wide separated by strips seven feet wide. In each series there are seven test plots, four treated with manure or fertilizer, and three checks. The purpose of the experiment was to test the relative value of manure and commercial fertilizers applied to different rotations.

At first only one crop of the rotation was grown each year, but in 1911 the plots were divided so that each crop of the rotation is grown every year. As a result some plots are smaller than others.

The accompanying map will give some idea of the relative size and position of the plots.

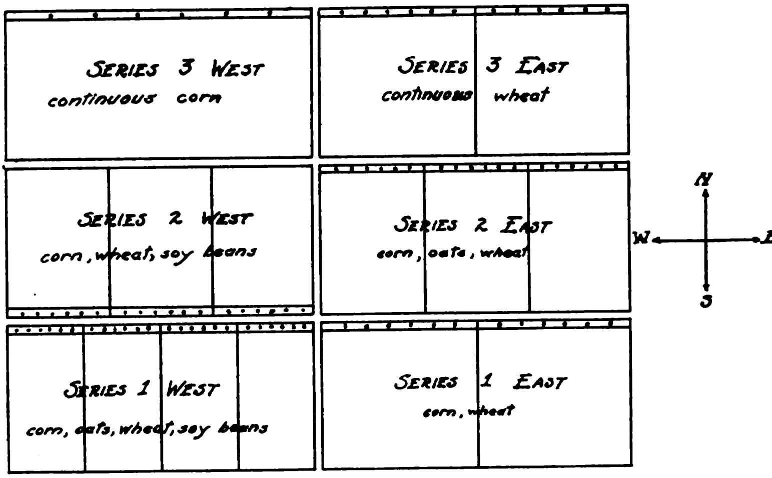
History of Literature.

Until within a generation ago it was not known that nitrification was a bacterial process. The transformation of organic nitrogen was regarded as a purely chemical reaction and was extensively studied from that standpoint.

The work of Kuhlman, Bossingault, Schlosing and Muntz, Warrington and Winogradski and other investigators showed the true nature of nitrification and the organisms responsible were isolated and studied.

PLATE I MAP OF PLOTS

Shows check plots from which samples were taken.
Dots show location of borings



Later investigations have brought out many of the factors influencing the process in the soil.

In 1893 Deherain,[2] and later in 1901 King and Whitson,[3] compared soil stirred and soil not stirred, and found that nitrates were produced more rapidly in the stirred soils. This they attributed to better aeration.

In experiments conducted in 1907, Voorhees, Lipman and Brown,[6] found decomposition slower under oats and clover than in bare soils.

In later studies King and Whitson,[3] found differences in the nitrates produced under the same crop in different plots and under different crops. Although the differences in some cases were quite considerable, they did not feel justified in drawing any conclusions relative to the effect of certain crops.

Later Deherain,[2] claimed that if soil moisture was not lacking, and if the loss of nitrate nitrogen in the drainage water and the nitrogen in the crop were added, similar nitrification would be found in fallow and in cropped lands. This statement, however, has been severely criticized and with respect to the question of nitrification under legumes, a proposition which has received considerable attention, experiments have shown that sometimes more and sometimes less nitrate nitrogen may be found than under grain crops. Among the more recent experiments are those performed by Brown[1] of Iowa which shows the following:

1. "The rotation of crops brought about a greater nitrifying power in soils than continuous cropping either to corn or to clover.

2. A soil under a three-year rotation of corn, oats and clover possessed a greater nitrifying power than one under a two-year rotation

of corn and oats, or one under a two-year rotation in which clover and cowpeas were used as a green manure.

3. There was an indication that the influence of the crop present on the soil was greater than the influence of the previous cropping on the bacteria in the soil, and this was probably due to the difference not only in the crop but in the treatment of the soil and preparation for the crop."

Technic.

The object of this investigation was to determine the effect of different crops and crop rotations on the nitrate content and nitrifying power of the soil.

To accomplish this end samples were taken monthly from each plot over a period from March, 1920, to October, 1920, inclusive, and these samples were analyzed for moisture, nitrates and nitrifying power.

Samples were taken at as near the same date each month as circumstances would permit. In order to eliminate as nearly as possible the factor of denitrification, no samples were taken when the soil was wet enough to "ball up".

Samples were evenly distributed over the plot as shown by dots on the accompanying map, and were taken from about the same places each month. In order to eliminate the factor of fertilizer, the samples were taken from the check plots of each series. (The check plots on the south side of Series V West were used because those on the north side were considerably lower than those of the other series.)

Moisture determinations were made by drying in an oven at 100° C for several hours, duplicate samples of 10 gms. soil each in 30 c.c. tarred crucibles.

The nitrate content was determined by the phenol-di-sulphonic method, as modified by Noyes[5] for soil investigation work.

To determine the nitrifying power of the soil, duplicate samples of 100 gms. each were placed in glass tumblers covered with petri plates, and incubated at room temperature for two weeks. In any instance where the moisture content was noticeably lower than normal, which ran about 20 per cent, distilled water was added to bring it back to normal. At the end of two weeks nitrate determinations were made as in the case of the fresh samples.

In tabulating the data the averages of the duplicates were used, and the nitrate content calculated on the basis of moisture-free soil and in terms of parts per million parts of water-free soil.

Discussion of Results.

Before entering into a discussion of the tables it would be well to note that the factors affecting bacterial activities and hence nitrate formation in the soils as determined by previous investigators are, moisture, temperature, aeration, crop growth, organic matter and plant food content of the soil, presence of toxic substances, cultivation, previous cropping and treatment, and type of soil. Of these many factors, those which may be taken as different in the different plots are aeration, kind of crop grown, cultivation, previous crop and treatment, and

possibly the presence of toxic substances. However, the last named factor is probably of very little importance. The effect of these differences can only be estimated in comparing plots.

The nitrate content of the fresh samples is taken as an indication of the surplus of the amount produced over that used by the crop.

The difference between the incubated and fresh samples is taken as a measure of the additional work done in the laboratory under optimum conditions by those groups of bacteria which change the nitrogen of complex organic nitrogenous compounds first into ammonia, then into nitrites and further to nitrates.

TABLE I.

Series I East—Rotation Corn, Wheat

Month	Plot 1 Wheat			Plot 2 Corn		
	Moisture %	Nitrates—Parts per million		Moisture %	Nitrates—Parts per million	
		Fresh Samples	Incubated Samples		Fresh Samples	Incubated Samples
March	21.4	28.45	65.04	20.20	16.42	32.85
April	21.1	4.04	26.31	21.70	8.16	36.73
May	17.23	3.86	19.30	16.48	3.83	19.12
June	12.58	1.83	21.96	18.49	35.30	82.35
July	16.99	11.56	15.41	15.28	79.32	83.01
Aug.	14.16	7.45	9.07	15.05	132.62	188.30
Sept.	11.98	....	3.62	15.10	26.36	56.52
Oct.	22.93	....	4.14	22.48	12.38	24.76
Total per period		57.19	164.85		194.39	523.64
Ave. per month		7.15	20.60		24.29	65.45

Discussion of Table 1.

Series I East—Rotation Corn, Wheat.

The average nitrate content of the entire period for the fresh samples for the corn plot is 24.29 parts per million, as compared to 7.15 parts for the wheat plot.

The highest content for fresh samples was reached for corn in August, just after the corn ceased drawing heavily on the nitrates of the soil. The highest content for the wheat plot was in March, before the crop started good growth, but a second high nitrate content was found in July, just after the crop was removed.

The fresh samples for the corn plot showed low from March to June, high from June to September, and low again for September and October. The wheat plot was high in March, low until July, high for July and August, and low again for the remainder of the period.

For the corn plot, the incubated samples show a much higher average for the eight months than do those of the wheat plot,—for corn 65.45 parts, and for wheat 20.60 parts of nitrates per million parts of moisture-free soil.

It will be noticed that the incubated samples for corn showed highest in August, for wheat highest in March. As would be expected, the incubated samples showed highest during the growing season and lowest during the months of less favorable conditions for bacterial action.

During the first part of the season these crops were feeding heavily on the nitrates of the soil, but the corn plot produced a larger surplus over the amount used than did the wheat plot. These differences noted above are in large part due to the corn crop being cultivated and having a larger growing season, thus making a longer period of more favorable conditions for bacterial activities.

TABLE 2

Series II East—Rotation Corn, Oats, Wheat

Month	Moisture %	Plot 1 Corn		Moisture %	Plot 2 Oats		Moisture %	Plot 3 Wheat	
		Nitrates—Parts per million			Nitrates—Parts per million			Nitrates—Parts per million	
		Fresh Samples	Incubated Samples		Fresh Samples	Incubated Samples		Fresh Samples	Incubated Samples
March	22.5	8.24	32.98	22.1	28.74	55.44	21.30	22.35	38.61
April	23.8	5.24	29.35	20.45	14.04	40.16	21.00	12.10	40.48
May	19.65	3.97	25.84	17.22	5.79	23.16	17.07	9.63	25.04
June	18.05	15.61	63.28	11.01	3.59	14.36	12.70	3.66	32.96
July	16.05	38.11	64.76	17.21	7.73	23.19	14.18	11.18	24.20
August	18.07	58.58	73.52	17.23	7.73	15.46	16.44	7.65	9.52
September	13.11	25.91	44.18	19.84	11.95	25.94	16.07	3.81	9.20
October	24.52	4.22	10.59	22.85	4.41	12.44	12.95	2.08	8.30
Total for period		151.84	344.47		83.71	210.15		72.46	188.31
Ave. per month		18.98	43.05		10.46	26.26		9.05	23.53

Discussion of Table 2.

Series II East—Rotation Corn, Oats, Wheat.

Table 2 shows that the average for the fresh samples for the eight months were corn, 18.98 parts, oats 10.46 parts, and wheat 9.05 parts of nitrate per million parts of moisture-free soil.

The highest nitrate content of the fresh samples was found in August for the corn plot, in March for the oat plot and in March for the wheat plot. The corresponding low content was found in May for corn, in June for oats, and in June for wheat.

The untreated samples showed an average of 43.05 parts for the corn plot, 26.26 parts for the oats and 23.53 parts for the wheat. The highest content for the corn plot was found in August, with June and July also high; for oats in March with several other months of the growing season high.

The similarity in the nature and feeding habits of the oat and wheat crops can be correlated with the similarity in the results for these crops. The difference between the results of the corn plot and these plots is in all probability due mostly to the difference in lengths of growing season and the cultivation received by the corn crop.

Discussion of Table 3.

Series III East—Continuous Wheat.

Table 3 shows an average for the eight months for the nitrate content of the fresh samples of 14.66 parts per million for the unlimed continuous wheat plot, and 12.78 parts per million for the limed plot.

TABLE 3

Series III East—Rotation Continuous Wheat

Month	Moisture %	Plot 1 Unlimed		Moisture %	Plot 2 Limed	
		Nitrates—Parts per million			Nitrates—Parts per million	
		Fresh Samples	Incubated Samples		Fresh Samples	Incubated Samples
Mar.	21.5	28.51	40.73	22.4	26.80	43.29
Apr.	18.35	21.55	50.88	21.0	4.05	36.43
May	15.48	7.56	26.46	16.15	11.42	26.66
June	10.65	14.30	3.57	9.01	7.03	31.63
July	12.23	10.93	21.85	13.17	11.05	33.14
Aug.	14.50	11.21	17.92	15.88	11.40	15.99
Sept.	15.28	16.98	22.68	13.03	22.47	33.10
Oct.	23.16	6.24	20.82	24.37	8.46	19.03
Total per period		117.28	204.91		102.28	239.27
Ave. per month		14.66	25.61		12.78	29.90

The content of the fresh samples for the unlimed plot was high in March, April, and fairly high in June, July, August and September, while that of the limed plots was high in March and September, and fairly high in June, July, and August.

The incubated samples gave an average of 25.61 parts for the unlimed and 29.90 parts for the limed. Here again the samples taken during the growing season contained the most nitrates.

The addition of lime to the soil brings about conditions more favorable to plant growth and bacterial activities. This in all probability accounts for the higher averages of the treated and untreated samples of the limed plots compared with the unlimed plots. The limed wheat no doubt made greater growth during the months of April, May and June than did the unlimed wheat, and therefore the fresh samples showed a lower average than those of the unlimed wheat.

TABLE 4

Series I West—Rotation Corn, Oats, Wheat, Soybeans

Month	Moisture %	Plot 1 Oats		Moisture %	Plot 2 Wheat	
		Nitrates—Parts per million			Nitrates—Parts per million	
		Fresh Samples	Incubated Samples		Fresh Samples	Incubated Samples
Mar.	21.8	20.44	39.87	22.3	28.80	49.18
Apr.	20.60	14.10	37.45	22.2	12.32	36.96
May	16.55	3.83	21.07	16.12	7.61	28.47
June	12.61	1.83	21.96	16.09	3.81	30.47
July	14.90	11.28	22.56	13.14	11.05	25.78
Aug	18.07	7.81	9.96	17.78	7.78	15.56
Sept.	11.79	9.05	21.76	12.61	5.48	10.98
Oct.	22.17	6.16	12.33	22.74	4.14	8.28
Total per period		74.50	186.96		80.99	205.68
Ave per month		9.31	23.37		10.12	25.71

DISCUSSION OF TABLE 4.

Series I West—Rotation Corn, Oats, Wheat and Soybeans.

The average of the nitrate content of the fresh samples for the period was 11.92 parts per million parts of moisture-free soil for the

TABLE 4—Continued

Month	Moisture %	Plot 3 Beans Nitrates—Parts per million Fresh Samples	Plot 3 Beans Nitrates—Parts per million Incubated Samples	Moisture %	Plot 4 Corn Nitrates—Parts per million Fresh Samples	Plot 4 Corn Nitrates—Parts per million Incubated Samples
Mar.	21.1	12.14	32.38	20.8	4.15	20.20
Apr.	18.6	1.96	19.64	19.75	1.99	23.90
May	14.98	3.75	20.67	15.95	3.80	19.01
June	14.58	14.90	114.73	14.93	18.80	48.87
July	13.36	40.62	40.59	17.5	42.66	54.26
Aug.	13.41	5.54	5.54	17.18	14.24	27.02
Sept.	9.78	3.54	10.68	15.95	5.70	17.12
Oct.	21.33	2.04	4.06	21.39	4.09	10.24
Total per period		84.49	248.29		95.43	220.62
Ave. per month		10.56	31.03		11.92	27.57

corn plot, 9.31 parts for the oats, 10.12 parts for the wheat, and 10.56 parts for the soybean plot.

The highest content of the fresh samples was found in July for the corn plot, in March with April and July also high for the oat plot, in March with April and July also high for the wheat plot, and in July with March and June high in the case of the soybean plot. During the latter part of the period, when conditions were less favorable for the formation of nitrates, and during the months of heaviest crop growth, the content of the fresh samples ran low for all plots.

Table 4 shows an average nitrate content for the incubated samples of 27.57 parts per million parts of moisture-free soil for the corn plot, 23.37 parts for the oat plot, 25.71 parts for the wheat plot and 31.03 parts for the soybean plot.

The highest content of the incubated samples was found in July for the corn plot, in March for the oat and wheat plots, and in June for the soybean plot.

The results for the corn and soybean plots check very closely with each other in regard to high and low periods and also the averages of the fresh and incubated samples. Both are cultivated crops. Also, as would be expected, the results on the oat and wheat plots check closely.

Discussion of Table 5.

Series II West—Rotation Corn, Wheat and Soybeans.

Table 5 shows the average nitrate content of the fresh samples for the eight months to be 32.60 parts of nitrate per million parts moisture-free soil for the corn plot, 7.64 parts for wheat and 7.48 parts for the soybean plot.

The corn plot contained the highest amount of nitrates in August, with June and July also high; the wheat plot showed highest in March, with April, May and July also high; the soybean plot contained most nitrates in June and July.

The corn plot showed an average of 59.58 parts in the incubated samples, the wheat plot an average of 20.80 parts, and the soybean plot an average content of 28.12 parts nitrates per million parts moisture-free soil. The highest results for these samples were found in August,

TABLE 5.

Series 1 West—Rotation Corn, Wheat, Beans.

Month	Moisture %	Plot 1 Corn: Nitrates—Parts per million: Fresh Samples	Plot 1 Corn: Nitrates—Parts per million: Incubated Samples	Moisture %	Plot 2 Wheat: Nitrates—Parts per million: Fresh Samples	Plot 2 Wheat: Nitrates—Parts per million: Incubated Samples	Moisture %	Plot 3 Beans: Nitrates—Parts per million: Fresh Samples	Plot 3 Beans: Nitrates—Parts per million: Incubated Samples
March	25.5	12.87	37.55	20.4	18.07	42.16	22.5	4.12	37.11
April	27.7	6.63	22 12	21.1	12.14	36.43	22.2	4.11	36.96
May	18.37	5.87	35.18	18.88	9.84	27.55	17.27	1.93	19.30
June	17.41	38.70	88.97	12.38	3.65	18.24	16.13	19.00	53.33
July	18.23	78.27	93.75	17.39	7.74	19.34	15.32	18.85	33.96
August	19.76	99.60	179.28	16.26	5.73	8.74	18.96	5.92	13.80
September	14.58	14.79	7.48	14.30	1.86	5.60	14.11	1.86	22.35
October	22.56	4.13	12.38	23.44	2.09	8.36	21.59	4.08	8.16
Total per period		260.86	476.71		61.12	166.42		59.87	224.97
Ave. per month		32.60	59.58		7.64	20.80		7.48	28.12

June and July for the corn plot, in March, April and May for the wheat plot, and in March, April, June and July for the soybean plot.

The highest results for the corn and soybean plots conform very closely to the period of cultivation, while the highest results for the wheat plot were obtained just before and immediately after the growing season, for the fresh samples, and from March to August for the incubated samples.

TABLE 6.

Series III West—Continuous Corn.

Month	Moisture %	Plot 1 Corn: Nitrates—Parts per million: Fresh Samples	Plot 1 Corn: Nitrates—Parts per million: Incubated Samples
March	25.4	21.41	34.26
April	27.5	4.43	22.02
May	18.32	29.35	78.27
June	15 88	22.80	60.83
July	18.01	42.93	50.68
August	16.63	14.97	40.22
September	14.17	9 31	18.63
October	22.21	6.17	8.23
Total for period		151.37	313.14
Ave. per month		18.92	39.14

Discussion of Table 6.

Series III West—Continuous Corn.

The average nitrate content of the fresh samples for the period was 18.92 parts of nitrate per million parts of moisture-free soil. The content was high from March to July, inclusive, with the exception of the month of April, the sample for which was taken just after the plot was plowed, and was lower from August to October. The highest point was reached in July.

The average for the incubated samples was 39.14 parts of nitrate. The months of May, June and July were highest, but the first six months all showed a high content for the incubated samples.

TABLE 7.

Nitrifying Power—Difference Between Fresh and Incubated Samples.

Series		Nitrates-Parts Per Million								
Number and Rotation	Plot No. and 1920 Crop	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Ave.
I, E.—	1 Wheat...	36.59	22.27	15.44	20.13	3.85	2.62	3.62	4.14	13.58
Corn, Wheat.......	2 Corn.....	16.43	28.57	15.29	47.05	3.69	55.68	30.16	12.48	26.17
II, E.—	1 Corn.....	24.74	24.11	21.87	47.67	26.65	14.94	18.27	6.27	23.07
Corn, Oats, Wheat..	2 Oats.....	26.70	26.12	17.37	10.77	15.46	7.73	13.99	8 30	15.81
	3 Wheat...	16.26	28.38	15.41	29.30	13.02	1.87	5.39	6.22	14.48
III, E.—	1 Unlimed..	12.22	29.33	18.90	10.73	10.92	6.71	5.70	14.58	10.95
Cont. Wheat.......	2 Limed...	16.49	32.39	15.24	24.60	23.09	4.59	10.63	11.57	17.32
I, W.—	1 Oats.....	19.43	34.59	17.24	20.13	11.28	2.15	12.71	6.17	15.46
Corn, Oats, Wheat	2 Wheat...	20.38	24.64	20.86	26.63	14.73	7.78	5.50	4.14	15.58
Beans...........	3 Beans....	20.24	17.68	16.92	99.83	—.03	0.	7.14	2.02	20.48
	4 Corn.....	16.05	21.91	15.21	30.07	11.60	13.38	11.42	6.13	15.72
II, W.—	1 Corn.....	24.68	15.49	29.31	50.27	15.48	79.68	7.31	8.25	26.98
Corn, Wheat, Beans.	2 Wheat...	24.09	24.29	17.71	14.59	11.63	3.01	3.74	6.27	13.17
	3 Beans....	32.99	32.85	17.37	34.33	15.11	7.88	20.49	77.52	29.81
(Cont. Corn) III, W............	1 Corn.....	12.85	17.59	48.92	38.03	7.75	25.25	9.32	2.06	20.22
Ave. all Plots..	....	21.34	25.33	20.21	32.89	12 28	15.47	10.51	11.87	

DISCUSSION OF TABLE 7.

Nitrifying Power of the Various Plots as Determined by the Differences between the Untreated Incubated and the Fresh Samples.

The averages for the period of the differences between the untreated and fresh samples are 13.58 parts, 14.48 parts, 10.95 parts, 17.32 parts, 15.58 parts and 13.17 parts of nitrates per million parts of moisture-free soil for the plots containing wheat. The lowest average was found for the unlimed continuous wheat plot, and the highest average for the limed continuous wheat plot.

The averages for the period for the corn plots were 26.17 parts, 23.07 parts, 15.72 parts, 26.98 parts and 20.22 parts of nitrate per million parts of moisture-free soil. The lowest difference, 15.72 parts, was for the corn plot in the corn, oats, wheat, soybean rotation, Series I. W., which plot also showed a low average for the fresh samples. This plot contains a large amount of gravel when compared with the other plots.

The averages for the oat plots were 15.81 parts and 15.46 parts of nitrate per million parts of moisture-free soil.

The averages for the soybean plots were 20.48 parts and 29.81 parts per million.

These results in Table 8 show that the nitrifying power of the corn and soybean plots as measured by this test is nearly the same, and is much higher than the nitrifying power of the wheat and oat plots, which plots are about equal in nitrifying power.

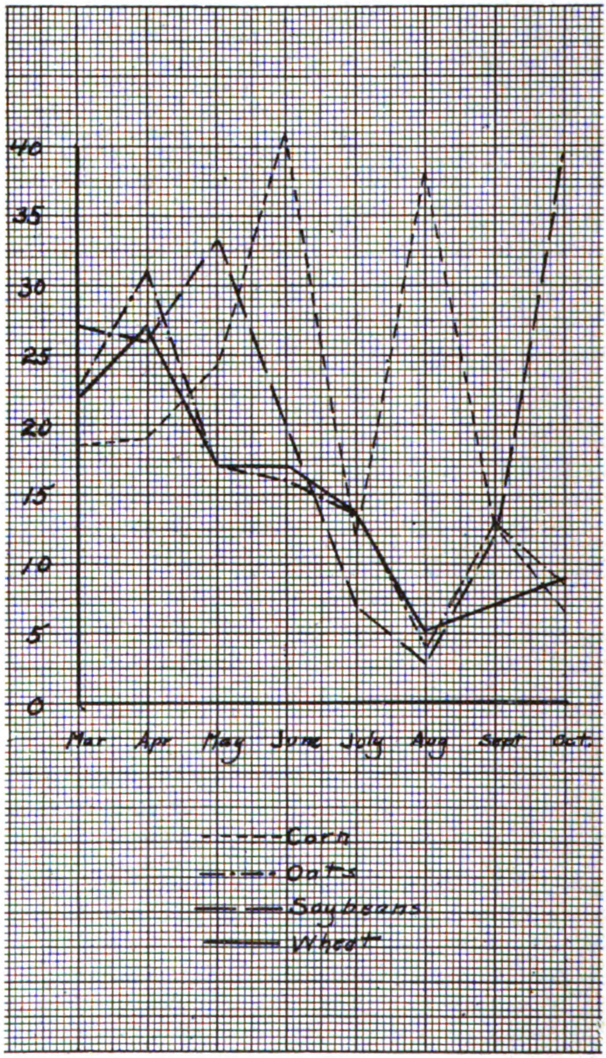


FIGURE I.
Nitrifying Power of Crops.

Discussion of Table 8.

Effect of Different Crops on Nitrifying Power of the Soil Measured by the Averages of all Plots Growing the Same Crop.

In Table 8 the differences between the incubated and fresh samples for all the corn, all the wheat, all the oats and all the soybean plots, are averaged and tabulated.

The curves for these averages are shown in Figure I.

TABLE 8.

Nitrifying Power—Difference between Fresh and Incubated Samples.

Crop	Average of Nitrates—Parts Per Million								
	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Ave. Mo.
Corn	18.95	19.53	26.12	42.61	13.03	37.78	12.37	7.04	22.18
Oats	23.06	30.35	17.30	15.45	13.37	4.94	13.35	7.23	15.63
Wheat	21.00	26.89	17.26	17.42	12.87	4.43	7.56	7.82	14.65
Beans	26.61	25.26	32.92	22.36	7.55	3.94	13.81	39.77	21.48
Average	22.40	25.51	23.40	24 46	11.70	12.77	11.77	15.46	....

The highest average difference between the fresh and incubated samples was found in June for the corn plots, in April for the oats and wheat plots, and in May for the soybean plots. The amount of nitrates used by the crops and leached from the soil would affect this curve directly.

Summary.

1. The rate of nitrate formation is very greatly increased by cultivation of the soil.

2. The corn and soybean plots, which were cultivated, showed a high nitrifying power as compared to the wheat and oat plots, which were not cultivated during the growing season.

3. The effect of the previous crop and treatment of the soil on nitrate production is not nearly as important as that of the growing crop and the soil treatment.

4. Corn and soybeans are heavy feeders while wheat and oats are less vigorous nitrate feeders.

5. The highest nitrifying power as determined by the methods employed in this work was in July for the corn plot, and in June for the wheat, oat and soybean plots.

6. The addition of lime to acid soils makes conditions for the development of nitrifying bacteria much more favorable.

7. The rate of nitrate production in the plots in the Purdue Experiment Station Field No. 6 is not a limiting factor to plant growth.

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FERTILIZER TREATMENT AS AFFECTING NITRATE PRODUCTION.

I. L. BALDWIN, W. E. WALTERS AND F. K. SCHMIDT.

Nitrate production is one of the most important problems of soil fertility. The ability of a soil to produce sufficient amounts of nitrate nitrogen for desirable plant growth over and above the natural losses, as denitrification and leaching, depends primarily upon soil management and treatment.

The problem of the farmer is to know the methods that can be employed to furnish and maintain this element in available form most economically. Natural losses occur more readily than in the more stable compounds of potassium and phosphorus.

There are many factors entering into the production and utilization of this important plant food and it has been the purpose of this investigation to try to throw some light upon a few of them.

REVIEW OF PREVIOUS WORK.

It has been known for a long time that nitrates are formed from organic nitrogenous substances in the soil. Investigators were discussing the process as far back as the middle of the nineteenth century. At that time they considered it as a purely chemical process. The great chemist Liebig held this view and his support was probably the reason that the actual cause of nitrification was not discovered at an earlier period. Boussingalt 1860 showed that the nitrogen of nitrate was not derived from the air.

It was demonstrated by Schloessing and Muntz 1878 that microorganisms in the soil oxidized ammonia to nitrate. His conclusions were drawn from the work he did on sewage disposal. Since this time many attempts were made to isolate the organism in pure culture and it was not until about 1890 that this was accomplished.

King and Whitson (2) found that nitrates were produced more rapidly in stirred soil due to better aeration.

Brown (4) concluded that media prepared from soil extracts permitted fewer organisms to develop than the modified synthetic agar. Fresh soil offers conditions as closely approximating field conditions as possible.

Lyon, Bizzell and Conn (5) state that a very definite relation exists between the crop yields and nitrate contents of the soil. Higher yielding plots show a larger accumulation of nitrates before planting than do the very low yielding plots. Evidently higher yields in these plots are associated with a more rapid formation of nitrates.

Brown (7) ran nitrification tests to find the nitrifying power of the soil. He treated the soils with dried blood and with ammonium sulphate. His tests show agreement to crop producing power of the soil, that is, the high nitrifying soils produced large crops.

Brown and Halversen (10) concluded that the number of molds present in the soils fluctuated from one sampling to the next but was

apparently unaffected by moisture, temperature or soil treatment. Some factors as yet uninvestigated probably account for the fluctuation. The small number of molds in soil compared with bacteria may not necessarily mean that they are less important and certainly will not prove that they are unimportant.

Greaves and Carter (12) found in their study of twenty-two soils that each one gave a maximum ammonification when its water content was sixty per cent of its water holding capacity. Nitrification was at its maximum at fifty or sixty per cent and varied with specific soils.

Whiting and Schoonover (13) conclude that soil treatment is a very important factor in nitrate production.

History of the Plots.

The field where this experiment was carried on is a part of the Purdue Experimental plots and is located on a brown silt loam underlaid with gravel at a depth of about two feet. It has been classified by the United States Department of Soils as a Sioux Silt Loam.

The field consists of thirteen one-sixteenth-acre plots. The first, fifth, ninth, and thirteenth plots are untreated or check plots and the other nine received the treatments shown in Table 1. The crop rotation of the field consists of corn, oats, wheat, clover and timothy. In 1920, the year this experiment was conducted, the field was in oats followed by fall sown wheat.

This field was laid out in 1889 and the different treatments were begun in 1890. A different system of treatment was used at first and it was not until 1918 that the present treatment was started, the field having received no treatment during 1917. The object of the change of treatment, which involved only the amount and method of application, was to secure more efficient use of the nitrogen applied.

TABLE 1

Series IV East—Field 6—Purdue Farm
Fertiliser Treatment in Pounds Per Acre

Plot No.	Corn	Oats	Wheat	Clover	Timothy	Treatment
1	None	None	None	None	None	Check
2	12,000	6,000	6,000	None	6,000	Horse Manure
3	12,000	6,000	6,000	None	6,000	Cattle Manure
4	N 30	N 15	N 15	None	N 15	N. P. K.
	P 30	P 15	P 15	....	P 15	
	K 30	K 15	K 15	....	K 15	
5	None	None	None	None	None	Check
6	N 30	N 15	N 15	None	N 15	N. P. —
	P 30	P 15	P 15	....	P 15	
7	P 30	P 15	P 15	None	P 15	
	K 30	K 15	K 15	....	K 15	— P. K.
8	N 30	N 15	N 15	None	N 15	N — K
	K 30	K 15	K 15	....	K 15	
9	None	None	None	None	None	Check
10	P 30	P 15	P 15	None	P 15	— P —
11	N 30	N 15	N 15	None	N 15	N —
12	K 30	K 15	K 15	None	K 15	— K
13	None	None	None	None	None	Check

Rotation Corn, Oats, Wheat, Clover and Timothy—
P=lbs. P_2O_5 per acre.
K=lbs. K_2O per acre.
N=lbs. N per acre.

Although there is now more total nitrogen applied to the manure plots than is applied to the plots receiving nitrogen in commercial form, the nitrogen in the manure must be converted into soluble nitrate while the commercial nitrogen is applied in the readily available form of nitrate of soda, so that the available nitrogen on these plots is probably comparable.

OBJECT OF THE INVESTIGATION.

Although a great many investigations have been conducted in a study of nitrification, few pertain to comparisons of the efficiency of different fertilizer treatments for nitrate production. The following points were deemed important in this study and they express the aim of this work.

1. The comparison of the amount of nitrate nitrogen produced in the same field but with different fertilizer treatment.
2. Correlation between amount of nitrate production and crop yield.
3. Correlation between nitrates found in the soil under natural conditions with growing crops and amount accumulating under optimum conditions.
4. Nitrifying power of a soil compared to crop growth and nitrate content in a fresh soil.
5. Comparison of the effect of soil treatments on bacteria and molds.

TECHNIC.

There was no effort made to discover or try out new methods in this work and the technic employed was adapted to the needs and conditions of this experiment from methods already in common use in soil nitrate and bacteriological studies.

The monthly sampling time varied from the twentieth to the end of the month, but all samples for each month were taken on the same day. The time chosen for taking samples was when all conditions were most favorable thereby lessening the possibility of denitrification occurring during the incubation period. Sampling was done with a soil auger, ten borings made to a depth of ten inches were taken from representative parts of a plot. Judgment was exercised in taking the samples to make them as representative as possible of the soil of the plots.

The samples were taken from the field to the laboratory and all work performed with the fresh samples was done immediately, thus not allowing time for any material bacterial action to take place before the tests were started.

The soil from each plot was used for the following five tests:

1. Fresh nitrates;
2. Nitrates after two weeks incubation;
3. Nitrates after two weeks incubation plus ammonium sulphate;
4. Plate count of bacteria and molds;
5. Moisture content of the fresh soil.

The colorimetric method employing the phenol-di-sulphonic acid color reaction, as modified by Noyes (11) was used in determining the

amount of nitrates present. Although the accuracy of this method has been severely criticized it is the one most widely used and most practical for this type of work where comparative rather than absolute results are sought.

A one hundred gram aliquot of soil was weighed into tumblers marked for the respective plots 1A to 13A. Each tumbler was covered with a petri plate lid and set away in a locker. After two weeks incubation nitrates were determined as before.

One hundred grams of each sample were placed in tumblers marked 1B to 13B and one cubic centimeter of a ten per cent solution of ammonium sulphate was dropped over the soil in each tumbler. They were covered and incubated two weeks then tested as in the case of the fresh nitrates. In the case of both incubated samples when too dry equal amounts of distilled water were added to each tumbler or if too wet the covers were left off of each tumbler for equal periods until of the proper moisture content.

Duplicate plates were made of dilutions 1 : 100,000 and 1 : 1,000,000 from each sample. A 1 : 10,000 dilution was also plated for a few of the tests but the colonies were too crowded to make the count accurate. Several different media recommended by soil bacteriologists were tried in an effort to determine which of them would give the best growth of bacteria and not encourage the spread of molds over the plates. The following synthetic agar media seemed most satisfactory and was used through the major part of the investigation:

5 grams of sodium potassium tartarate;
.5 gram of di-basic potassium phosphate;
1 gram of peptone;
.2 gram of magnesium sulphate;
15 grams of agar;
1 liter of distilled water.

The plates were incubated for one week at room temperature before counting colonies of bacteria and molds. However, in two instances low temperature in the room deterred growth so that they were incubated longer.

TABLE 2.

Moisture Percentage.

Plot No.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Ave.
1	23.65	21.25	23.25	18.96	10.60	13.24	14.49	18.89	20.83	165.21	18.35
2	25.15	22.77	18.65	11.70	14.30	16.34	13.01	20.17	22.60	164.59	18.29
3	24.26	22.95	19.45	11.00	12.48	15.68	15.93	24.82	21.79	168.36	18.70
4	24.38	22.05	18.45	15.48	12.65	15.55	15.84	20.97	29.11	174.48	19.39
5	23.32	21.60	17.55	10.95	8.86	15.55	13.93	21.61	20.21	153.59	17.07
6	24.00	20.75	17.80	10.65	12.88	15.13	15.25	20.92	21.53	158.91	17.66
7	23.62	21.55	19.68	11.70	12.30	15.74	16.46	21.53	21.01	163.59	18.17
8	23.84	21.05	18.35	10.70	12.40	14.17	14.17	20.73	20.52	155.93	17.32
9	23.40	21.85	18.27	10.92	11.65	14.38	14.32	20.02	20.03	154.84	17.20
10	23.14	20.45	18.42	10.15	12.75	14.17	14.01	20.23	20.38	153.30	17.03
11	21.76	20.40	14.67	10.40	10.75	13.76	13.70	20.01	19.92	145.37	16.15
12	23.15	20.45	17.55	10.00	10.70	13.57	12.94	20.26	19.80	148.42	16.50
13	22.85	20.25	17.72	10.80	11.58	13.48	13.15	20.78	20.77	151.38	16.82
Total	306.52	277.37	239.81	153.41	153.90	190.77	187.20	270.94	278.50	....	226.43
Ave.	23.58	21.33	18.44	11.80	11.84	14.67	14.40	20.84	21.42	158.32	17.45

Ten gram samples were weighed into tarred crucibles and dried in an electric oven at a temperature of one hundred degrees centigrade for moisture determinations.

All calculations in the tables were based on moisture free soil. Nitrate parts per million were calculated on the average for the duplicates, however there was little variation in the duplicates. The bacteria and mold calculations were based on the average of the 1 : 100,000 dilution plates, except in a few cases where development was not normal. Calculations were then based on the 1 : 1,000,000 dilution plates.

Moisture Percentages (Table 2).

Moisture determinations were made in order to calculate the amount of nitrates produced on a dry soil basis. Although the moisture content of a soil probably does greatly influence nitrate production it was not primarily for the study of this factor that the moisture content of the samples was made in this experiment.

Table 2 shows that the range of moisture content between the plots in any one month is small, not over four per cent except in a few instances. Plots 1 and 4 were high in June causing a range of 8.96 per cent while the range for the remaining plots was less than two per cent. The highest moisture content occurred in March with a gradual decrease to June and July, which were nearly equal and lowest for the period.

The moisture content increased from August to the end of the period and the average for November was a little more than equal to April. But these figures cannot mean very much because this factor is largely dependent on the season and weather conditions at the particular time of sampling. The plot averages for the year showed a range of only 3.24 per cent. The average deviation from the average was only a .75 per cent. The moisture content of the soils of the different plots varied so little that it was probably a very small factor in causing the difference in the nitrate production of these plots.

TABLE 3

Molds

(Millions per gram of Dry Soil Calculated on a Dry Basis)

Plot No.	March	April	May	June	July	Sept.	Oct.	Nov.	Total	Ave.
1	1.57	1.40	.60	.12	.22	.17	.30	.44	4.84	.60
2	1.34	1.03	1.35	.45	.34	.28	.00	.32	5 13	.64
3	1.58	1.44	1.47	.33	.28	.23	.20	.25	5.80	.72
4	1.19	.83	.61	.41	.28	.29	.31	.21	4.16	.52
5	1.44	1.27	.36	.28	.11	.00	32	.88	4.67	.58
6	.72	3.79	.55	.50	.34	.17	.69	.44	7.22	.90
7	1.31	1.02	.62	.28	.40	.12	.44	.82	5.02	.62
8	1.77	.89	.37	.61	.28	.40	.44	.37	5.15	.64
9	1.31	.31	.67	.28	.22	.11	.25	.25	3.42	.42
10	.58	1.88	.35	.27	.63	.11	.50	.56	4.90	.61
11	.26	.87	.52	.27	.44	.11	.81	.43	3.75	.46
12	.71	1.57	.54	1.22	.28	.11	.44	.62	4.50	.56
13	.32	1.69	.60	.78	.34	.11	.63	.79	5.28	.66
Total...	14.10	18.02	8.64	5.85	4.20	2.27	5.40	6.42	....	7.98
Ave.....	1.08	1.38	.66	.45	.32	.17	.41	.49	4.99	.62

MOLD COUNTS EXPRESSED IN MILLIONS PER GRAM OF DRY SOIL (Table 3).

The results of mold counts given in Table 3 show that the mold counts of all plots averaged highest in March and April, gradually decreasing for May, June and July. The lowest count was for September, growth being very low at that time. The averages for October and November about equalled the average count for June.

The range in the counts for the different plots was wide, varying, for March, from .26 for the nitrogen plot, No. 11, to 1.77 for the N K plot, No. 8.

However, the range was usually much less as the count in September was from .11 for several plots to .40 for the N K plot, No. 8. This plot had a rather constant count, never falling below .37. This was much above the average for the July counts. The high average of plot 6 may have been due to an error since the April count was 3.79 while in March the count was only .72 and in May .55.

Mold counts for manure plots Nos. 2 and 3 were consistently above the averages for the monthly tests until October and November when the counts were much lower than the averages for these months. The cow manure plot, No. 3, had the higher count for March, April and May. But the horse manure plot, No. 2, had a little higher count for the remainder of the months, except in October when the failure of any growth to appear lowered the average count of Plot 2 noticeably below Plot 3.

Check Plot No. 9 had the low average count of .42 for the period. The N K Plot No. 8, had an average count of .64, which is .22 above this check plot. The P Plot, No. 10, had a count of .61, which is .19 above the check. But Plot No. 11, having only nitrogen treatment, has an average count of .46 which is approximately equal to the count of the check plot.

The potash and phosphorus treatments appeared to increase mold growth while nitrogen treatment had but slight effect. The average counts for check plots Nos. 1, 5 and 13 were considered equal to or higher than all the chemically treated plots. It would seem that either the source of error was very great, due perhaps to the small number of molds grown, or the various chemical treatments influenced mold growth but little.

BACTERIA COUNTS EXPRESSED IN MILLIONS PER GRAM OF DRY SOIL (Table 4).

Bacteria counts of all plots averaged high for March, April, and October, medium for June and July, low for May and September with November lowest of all.

The range of counts for March was from 2.61 for the N plot, No. 11, to 19.60 for the cow manure plot, No. 3. But the range for July was only from 2.64 for the complete fertilizer plot, No. 4, to 5.48 for the horse manure plot, No. 2.

The check plots Nos. 1, 5, 9, and 13 showed a lower average count for the period than the intervening treated plots. Check plot, No. 1,

TABLE 4.
Bacteria
(Millions per gram of Dry Soil Calculated on a Dry Basis)

Plot No.	March	April	May	June	July	Sept.	Oct.	Nov.	Total	Ave.
1	9.95	7.25	3.39	4.75	3.92	2.40	5.80	1.58	39.04	4.88
2	12 70	10.05	9.21	4.93	5.48	4.61	2.25	3.11	52.34	6.54
3	19.60	11.40	4.92	6.10	4.28	5.05	7.58	3.38	62.36	7.79
4	6.60	13.85	4.41	6.34	2.64	2.85	5.82	2.31	44.83	5.60
5	7.05	8.18	1.46	1.74	3.62	1.86	5.87	1.38	31.16	3.89
6	4.94	5.41	2.32	4.76	4.70	1.88	5.69	3.94	33.64	4.20
7	6.15	10.20	2.48	2 84	4.90	2.52	7.00	3.10	39.19	4.89
8	5.81	11.14	4.55	2.01	5.51	8.40	6.95	1.51	45.88	5.73
9	10.92	1.50	3.37	2.02	3.84	1.63	6.50	2.50	32.28	4.03
10	10.11	9.82	1.04	3.90	4.30	2.21	6.27	2.32	39.97	4.99
11	2.61	6.90	3.22	11.10	4.58	1.62	10.00	2.12	42.15	5.27
12	4.96	3.77	3.64	6.68	4.64	2.64	5.14	2.37	33.84	4.23
13	5.82	4.34	4.26	6.40	2.66	1.27	4.05	2.91	31.71	3.96
Total...	107.22	103.85	48.27	63.58	55.07	38.94	78.92	32.53	....	66.05
Ave.....	8.24	7.98	3.71	4.89	4.23	2.99	6.07	2.50	40.64	5.07

had an average count of 4.88 which was lower than the average count for plots Nos. 2, 3 or 4.

The manure plots Nos. 2 and 3 had the highest average counts. The count for the cow manure plot, No. 3, was higher, for March, April, June, September, October, and November, than the horse manure plot No. 2. The average count for the period was 1.25 greater.

Three of the four plots having nitrogen in their treatments had higher average counts for the period than plots receiving no nitrogen in their treatments. The N K plot No. 8, was high with 5.73, the complete fertilizer plot, No. 4, was next with 5.60 and the N plot, No. 11, was lower with 5.27. However, the N P plot, No. 6, shows a slightly lower count than the P plot, No. 10, and the P K plot, No. 7, but nearly equal to the average count of the K plot, No. 12.

The results seem to indicate that manure treatment causes greatest bacterial growth. The nitrogen in commercial fertilizer treatments usually encourage bacterial growth more than phosphorus or potassium. All treatments increased bacterial numbers over the no treatment plots.

Fresh Nitrate Expressed in Parts Per Million Per Gram of Dry Soil (Table 5).

The nitrate found in the fresh soil is not a real test of the amounts being produced. The amount of water present, due to physical condition of the soil, the amount lost by leaching, and the amount and rapidity of crop growth cause the nitrate content to vary unequally. The averages for the months indicate periods of consumption and excess production. The plot averages for the entire period probably indicate roughly the nitrate producing ability of the soil.

The amounts of soluble nitrates found to occur in the soils of the different plots at the monthly sampling times vary greatly. The plots average highest for March, medium for April, July, September, and November, low for October, May and August and lowest for June. The

TABLE 5

Fresh Nitrates

(Parts per million calculated on a Dry Basis)

Plot No.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Ave.
1	21.00	8.15	20.90	15.80	10.70	12.91	16.82	7.89	14.15	128.32	14.26
2	29.00	9.30	8.80	7.25	35.80	15.31	30.20	16.10	29.00	170.76	18.97
3	29.60	11.40	8.91	6.30	18.60	22.80	50.90	20.22	24.50	193.23	21.47
4	16.90	12.30	8.80	3.79	28.10	9.50	17.20	10.10	18.08	124.77	13.86
5	17.80	10.40	12.61	3.60	7.01	10.42	11.10	6.12	10.02	89.08	9.90
6	21.80	20.10	8.79	5.48	11.00	11.32	15.15	7.08	17.31	118.03	13.11
7	23.80	14.30	7.92	3.63	7.31	9.51	15.40	10.70	13.15	105.72	11.74
8	24.20	13.20	15.71	3.58	18.52	12.12	13.08	11.10	13.60	125.11	13.90
9	25.00	16.20	11.70	4.50	10.91	13.10	13.09	7.00	10.00	111.50	12.39
10	26.00	17.10	7.85	3.57	22.00	12.10	13.03	8.55	14.08	124.28	13.80
11	16.40	16.10	10.31	8.94	14.31	8.35	14.85	10.00	16.00	115.22	12.80
12	21.90	10.00	7.78	3.56	28.70	11.10	16.50	8.04	10.96	118.54	13.17
13	20.80	12.00	9.75	5.38	18.21	7.40	12.81	5.05	12.12	103.52	11.50
Total	294.20	170.55	139.83	75.38	281.37	155.94	230.13	127.45	203.07	....	181.87
Ave.	22.63	13.12	10.76	5.80	17.79	12.00	17.70	9.80	15.62	126.22	14.00

low average nitrate content for June was probably due to the rapid crop growth and dry weather occurring at that time. But the low average for October was probably influenced by heavy rains just preceding the taking of the samples.

Manure plots Nos. 2 and 3 were highest for March and November. This was probably due to the residual effect of the manure. In contrast with these plots the N plot, No. 11 was lowest for March and low in November; this plot was higher than the manure plots for April, May, and June, and showed the least variation for the period.

The average parts of nitrate for check plot, No. 1, was .26 higher than the average for all plots. The other three check plots Nos. 5, 9 and 13 were all low with an average for the three of 11.26 or 2.74 parts lower than the average for all plots, and .48 lower than the lowest treated plot, No. 7.

The three plots Nos. 4, 6, and 8 receiving N P K, N P, and N K, respectively, had an average for the period of 13.62. But the average of the plots Nos. 7, 10, and 12 which received no nitrogen in their treatments was 12.90 for the period. This was .72 less than the average for the plots receiving nitrogen in addition to these treatments.

It seems, from these results, that check plot, No. 1, was influenced by the treatment from the manure plots next to it. Manure treatment had a tendency to produce nitrates continuously throughout the period.

Any one of the treatments increased nitrate content over no treatment. Nitrogen combined with phosphorus or potassium gave a higher nitrate content than when nitrogen was used alone or when phosphorus and potassium were used without nitrogen.

Nitrates After Two Weeks Incubation Expressed in Parts Per Million Per Gram of Dry Soil (Table 6).

This test was intended to show the amount of nitrates that would accumulate when the soil was placed under optimum conditions. It

TABLE 6.

Nitrates After Two Weeks Incubation.

(Parts per million calculated on a Dry Basis)

Plot No.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Ave.
1	21.00	30.60	48.01	35.51	75.00	17.50	11.20	9.86	16.15	264.83	29.42
2	25.80	31.00	47.21	29.02	157.00	31.40	20.20	14.05	27.90	383.58	42.62
3	30.80	29.10	47.60	27.91	157.00	13.50	44.60	12.75	39.95	403.21	44.80
4	25.40	31.80	29.42	35.03	74.10	19.01	13.31	10.10	27.04	265.21	29.47
5	27.10	26.60	40.81	14.41	57.00	40.00	13.00	12.25	16.05	247.22	27.47
6	21.00	28.20	33.00	17.90	75.00	12.37	15.15	10.10	19.36	231.78	25.75
7	21.00	26.60	31.91	14.51	68.51	19.00	12.50	10.20	22.25	226.48	25.19
8	23.10	36.60	32.00	26.92	81.40	7.46	9.34	12.15	20.08	249.05	27.67
9	23.00	36.40	29.31	18.01	65.40	18.60	9.35	10.00	17.00	227.07	25.23
10	16.70	23.20	31.42	17.83	73.40	14.95	13.21	12.05	19.05	220.81	24.53
11	16.40	24.00	31.01	17.85	51.00	14.88	14.85	12.00	24.95	206.94	22.99
12	20.80	21.10	45.82	14.21	35.80	14.85	14.50	10.05	16.92	194.05	21.56
13	20.80	20.00	35.00	14.30	58.09	12.96	9.22	12.16	20.20	202.64	22.51
Total	292.90	365.20	482.52	284.41	1,028.61	238.48	200.43	147.71	286.90	....	369.21
Ave..	22.53	28.09	37.12	21.88	79.12	18.20	15.72	11.36	22.07	255.79	28.41

differed from the fresh nitrate test in that moisture content was controlled and there was no loss of nitrates from crop growth or leaching.

Table No. 4 shows that the nitrate content of the soils was high for May and July, medium for April, low for March, June and November and very low for August, September and October.

The manure plots, Nos. 2 and 3, were high for March, April, and November. The averages of these plots for the period were about equal and much above the average of all plots.

The three plots 4, 6, and 8 receiving nitrogen in addition to phosphorus or potassium or both had an average nitrate content of 27.63 for the period. The average nitrate content was 23.79 for plots 7, 10, and 12 which received the same treatments except the nitrogen was left out.

The average of the three check plots 5, 9, and 13, was 25.07 for the period. The check plots in this case were slightly higher in nitrate content than the plots receiving either phosphorus or potassium or both. This difference was not marked but it may have been caused by a greater lack of nitrogen in the treated soil due to a larger crop growth. However, the average of the untreated plots was also higher than the plot receiving only the nitrogen treatment. The average of the plots 7, 10, and 12 which had no nitrogen in their treatments was slightly higher than the average for the N plot No. 11.

The increase in nitrate content of the incubated samples over that of the fresh soil samples was proportionately much less when the fresh nitrates were low as in June and October. The average on both tests was highest for the period in July. The July increase in nitrate content after incubation was 350 per cent. But in October the increase with incubation was only 15.9 per cent. The increase for the high month of July was 62.33 parts but the increase for the low month of June was only 16.08 parts.

It then would seem in this instance that periods of low nitrate content may indicate times of low nitrifying power of a soil. The results

seem to show that the addition of nitrogen to the phosphorus and potassium treatments causes the higher nitrate content of those soils.

TABLE 7.

Nitrates After Two Weeks Incubation and Addition of $(NH_4)_2SO_4$

(Parts per million calculated on a Dry Basis)

Plot No.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Total	Ave.
1	35.60	28.50	41.61	50.51	114.50	17.50	19.70	13.80	21.22	342.94	38.10
2	37.40	36.10	55.12	108.20	187.00	50.70	25.07	36.08	41.45	577.12	64.12
3	36.00	37 40	60.51	108.00	178.00	60.45	36.09	44.52	47.00	607.97	67.55
4	31.80	37.00	39.21	44.51	100.00	27.25	24.61	16.25	33.90	254.53	39.39
5	29.40	32.70	30.22	36.01	97.50	16.11	14 90	13.25	20 02	290 11	32.23
6	33.60	31 40	38.90	35.82	109.00	28.12	21.68	14.17	21.40	334.09	37.12
7	34 60	28.80	32.81	36 23	146.00	21.91	15.40	16.35	26.28	358 38	39.82
8	35.80	35.00	39 23	52.01	168.90	29.92	16 75	15 15	22.18	404.94	44.99
9	35.40	27.00	39.12	35.94	173.00	41.20	20.25	16.00	18.00	406.21	45.13
10	35.40	24.10	39.32	41.03	147.50	34.50	24.21	12.05	20.10	378 21	42.02
11	32.80	28.10	30.01	42.81	103.50	28.39	18.61	14.00	19.95	318.17	35.35
12	33.10	36.10	38.92	35.50	100.50	37.10	27.25	12.02	15.95	336.44	37.38
13	34.80	20.00	39.00	39.50	132.00	29.81	14.80	14.15	18.15	337.21	37.47
Total	445.70	422.50	523.98	666.07	1,747.40	422.96	279.32	237.79	325.60	....	560.67
Ave..	34.28	32.50	40.30	51.23	134.41	32.53	21.48	18.28	25.04	390.05	43.23

NITRATES AFTER TWO WEEKS INCUBATION PLUS AMMONIUM SULPHATE. EXPRESSED IN PARTS PER MILLION PER GRAM OF DRY SOIL Table 7).

This test was intended to show the efficiency of the different soils in changing a soluble nitrogen compound into nitrate nitrogen. Any lack of nitrogen was supplied and variations in the amounts of nitrates formed in the soils were dependent on their ability to change ammonia to nitrate. However, this ability cannot be directly attributed to the original soil treatments as their power may have been changed because of the influence of the nitrogen added.

The monthly averages of the nitrates for the plots in this test were high for May, June, and July, low for September, October, and November and medium for March, April, and August. The manure plots Nos. 2 and 3 were high throughout the period with a general average of 65.83. The cow manure plot, No. 3, was slightly higher, for the period, than the horse manure plot, No. 2. The most noticeable variation between these manure plots and the other soils in the study occurred in October and November when the manure plots were nearly twice as high as any other plot.

Variations among all other plots were small. The range for any month was usually less than fifteen parts per million. The range of averages for the period was from 32.23 for check plot No. 5 to 45.13 for check plot No. 9.

The average for the check plots Nos. 1, 5, 9 and 13, was 38.23 for the period. The average of the plots Nos. 4, 6, 8, and 11 receiving nitrogen in their treatments was 39.21 for the period. The average of plots Nos. 10, 12, and 7 receiving phosphorus, potassium, and phosphorus and potassium respectively, was 39.74. Although the average for the check plots was slightly lower than for the treated plots the

results as measured by this test seemed to show the nitrifying power of these soils to be very similar.

Comparing Tables 4 and 5 the results show that the nitrates in the ammonium sulphate treated samples were increased more for the fertilizer plots Nos. 7, 10, and 12 which received no nitrogen in their treatments, than were the nitrates for plots Nos. 4, 6, 8, and 11, which received nitrogen in their treatments. The average difference due to increase for the plots receiving no nitrogen in their treatments was 15.98. But the average difference for the plots receiving nitrogen in their treatments was only 12.74. The average difference due to increase was a little lower for the check plots, it being 12.12. The greatest increase occurred in the case of the manure plots which had an average difference of 22.12.

The results of this test seem to indicate that manure treated soil has the strongest nitrifying power because of the increased physiological efficiency of the bacteria. The check plot shows the lowest nitrifying power due to the lowered physiological efficiency of the bacteria. The treatment with phosphorus, potassium or both increased the nitrifying power of the soil. The nitrogen applied in the form of ammonium sulphate at the time this test was started made doubtful the effect of the original nitrogen treatments on the nitrifying power of the soils.

TABLE 8.

Table of Averages.

Plot No.	Per Cent Volatile Matter	Per Cent Moisture	Nitrate Parts Per Million on Dry Basis			Millions Per Gram of Dry Soil Calculated on Dry Basis	
			Fresh Soil	After 2 Weeks Incubation	After 2 Weeks Incubation Plus $(NH_4)_2SO_4$	Bacteria	Molds
1	6.10	16.13	14.26	29.42	38.10	4.880	.605
2	6.15	18.29	18.97	42 62	64.12	6.543	.641
3	5.91	18.70	21.47	44.80	67.55	7.795	.726
4	5.62	19.39	13.86	29.47	39.39	5.604	.521
5	5.75	17.07	9.90	27.47	32.23	3.895	.584
6	5.52	17.66	13.11	25.75	37.12	4.205	.903
7	5.90	18.17	11.74	25.19	39.82	4.899	.629
8	5.68	17.32	13.90	27.67	44.99	5 735	.645
9	5.75	17.20	12.39	25.23	45.13	4.035	.428
10	5.66	17.03	13.80	24.53	42.02	4.996	.613
11	5.66	16.15	12.80	22.99	35.35	5.270	.469
12	5.69	16.50	13.17	21.56	37.38	4.230	.563
13	5.86	16.82	11.50	22.51	37.47	3.964	.661

Table of Averages (Table 8).

Since it seemed that the plot averages for the period were a more accurate measure of the nitrate producing ability of the plots than figures for any one month, these plot averages for all the tests were brought together in Table 8. A study of this table as illustrated by Figure I shows that there is a direct correlation between bacterial activities and nitrate production. The nitrates were low in the fresh soil and correspondingly higher in the incubated soil. The highest nitrate production occurred in the ammonium sulphate treated soils. Bacteria and mold counts correlate closely, bacteria having the much higher count.

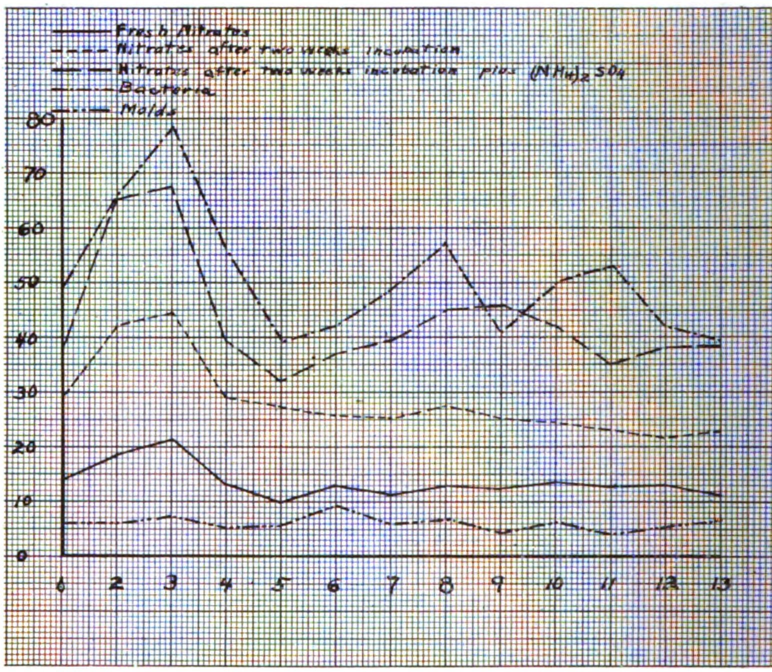

FIGURE I.
Correlation of Bacterial Activities and Nitrate Production.

Correlation of Bacterial Activities and Nitrate Production (Figure I).

This graph is based on the figures in Table 8. It can be readily seen that there is a marked correlation between these five basic factors. One noticeable disagreement may be seen in the case of the treated incubation test on Plot No. 9, when the nitrates were comparatively higher than in the other tests. Another disagreement occurs due to high bacterial counts for plots Nos. 10 and 11. With the exception of a few other minor differences these curves follow each other very closely.

Comparison of Crop Production With an Efficiency Factor (Figure II).

Any effort to compare the nitrate production and bacteriological efficiency of a soil with crop production makes it desirable that some common basis of comparison should be decided upon. For this purpose an efficiency factor for each of the tested plots was secured by adding together the parts per million of nitrates from the three tests with the mold and bacteria counts per million for each plot using the last five columns of figures in Table No. 8. The sums obtained for check plots Nos. 1 and 5 were added, divided by two, and the resulting figure taken

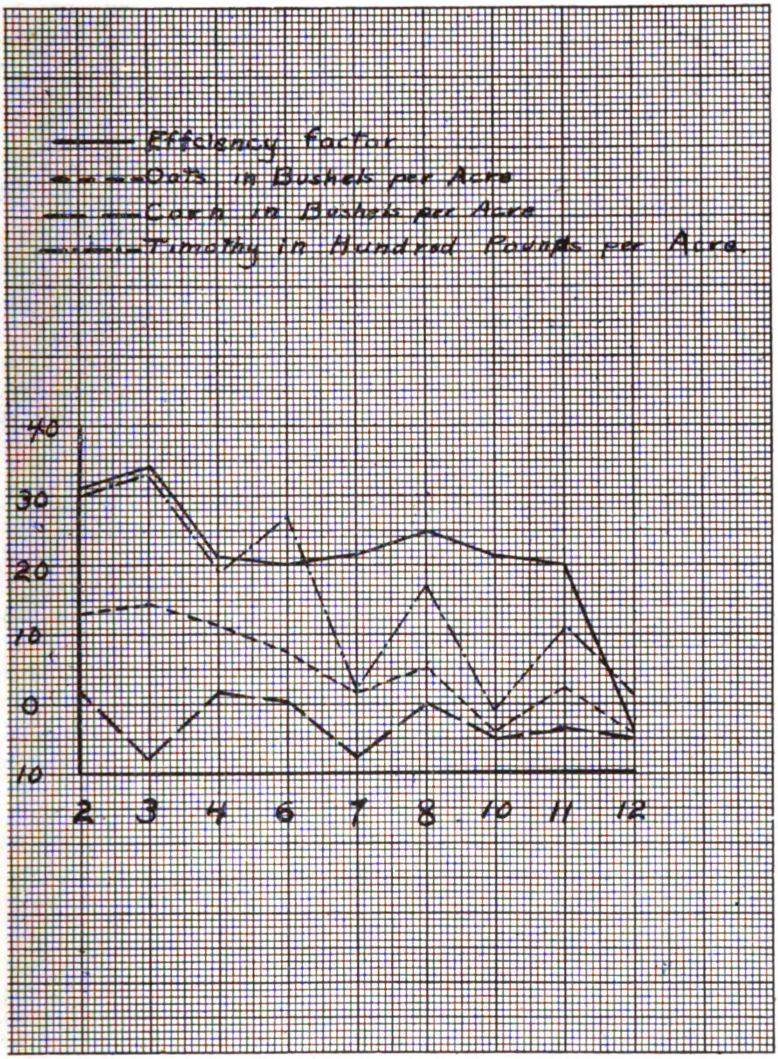

FIGURE II.
Comparison of Crop Production with an Efficiency Factor.

as 100. The intervening plots Nos. 2, 3, and 4 were then compared to this standard.

This efficiency factor was determined for all plots in a similar manner. The graphic crop yields based on a similar method of calculation were compared to the efficiency factor in Figure II. It is readily seen from this graph that there is a correlation of crop yield with biological activities and nitrate production. The closest correlation is shown by the oats and timothy yields. The yield of corn shows the

least correlation. Plot No. 3 has the highest efficiency factor and its corn yield was lowest of all the plots. Again in Plot No. 4 the efficiency factor goes down and the corn yield is highest of all the plot yields. However, for the remainder of the plots the yield and the efficiency factor show a close agreement.

SUMMARY.

A general study of the results of this experiment seem to show that the manure plots which were high in mold counts; highest in bacterial numbers; highest for fresh nitrates; equally high in incubated nitrates and very high in the ammonium sulphate treated samples, had the greatest efficiency for nitrate production. The cow manure treatment seemed to be somewhat more efficient than the horse manure treatment since the results of all tests were slightly higher in its favor.

Check plot No. 1, seemed to have been influenced by the manure treatment due to its nearness to those plots. The results from plot 1 usually were as high or higher than the average for all the plots and on the whole higher than the other check plots.

The use of nitrogen with phosphorus or potassium was superior to either of the treatments used alone for bacterial count and all nitrate tests except the ammonium sulphate treated samples where the difference was slight. Phosphorus and potassium treatments increased mold and bacteria growth, fresh nitrates and ammonium sulphate treated samples.

The results of ammonium sulphate treated samples which were least influenced by crop growth and seasonal variations seem to show that the greatest nitrifying power of a soil is in May, June and July. This power seems to decrease during the latter part of the summer and increase in the late fall and spring.

There seems to be a general correlation, when averages are taken for the entire season, between the amount of nitrate found in the soil under natural conditions with growing crops and the amount accumulating under optimum conditions. *Purdue University.*

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Nitrate Production in Field Soils in Illinois. Illinois Agricultural Experiment Station Bulletin 225.

INDEX.

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How to prepare standard manuscript.

1. Typewrite the manuscript on white paper of uniform size (8½x11); write only on one side and leave a margin of about 1¼ inches all around; double space between the lines.

2. In typewriting the text put the footnote numbers exactly where each reference belongs.

3. Typewrite all footnotes together and number them consecutively from 1 up. Explanations of figures should be treated in the same way, and like footnotes should be put at the end of the text copy.

4. When a table is reached in the text, stop. Remove the sheet. Take a new sheet of paper and typewrite the table. Then proceed with the text, on a new sheet, until the next table is reached when the same procedure should be repeated.

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6. Mark on the copy in ink the place where each illustration is to be placed.

7. Write at the top of the first page of copy, for the running page headline, a shortened title of not over 35 letters if the main title is longer.

8. Figures should be numbered from 1 up, including all figures in text or plates.

9. Draw all figures so they can be reproduced as line or half-tone engravings. In grouping the drawings bear in mind, that after the reduction has been made, the figures should not exceed the dimensions of the printed matter on the page, 4½x7 inches. Arrange the figures and lettering so as to make a neat appearance when printed.

The editor reserves the right to return manuscripts not prepared according to these suggestions.

PROCEEDINGS

OF THE

THIRTY-EIGHTH ANNUAL MEETING

OF THE

INDIANA ACADEMY OF SCIENCE

1922

PROCEEDINGS

OF THE

THIRTY-EIGHTH ANNUAL MEETING

OF THE

INDIANA ACADEMY OF SCIENCE

1922

J. J. DAVIS, EDITOR

INDIANAPOLIS:
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1923

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*Deceased. †Officers continued—Annual meeting not held because of influenza epidemic.

MINUTES OF THE SPRING MEETING.

French Lick, Indiana.

The Spring Meeting of the Academy afforded its members and friends an opportunity to study the remarkable Lost River district of Orange County. The underlying rocks of this region are limestone, and due to spectacular stream trenching, are largely responsible for the hills, valleys and caves of the present time.

In addition to exploring the Lost River basin, the party visited the springs and rock formations of the French Lick valley, including Cross Cave. Prof. C. A. Malott, together with other members of the Academy who were familiar with the region, acted as guides.

The meeting was planned to cover three days, Thursday, Friday and Saturday, May 11, 12 and 13, 1922.

Thirty-eight members and eleven guests were in attendance at the meetings and on the trips.

Thursday, May 11.

Members of the Academy and their friends met at the Windsor Hotel, French Lick. At 2:00 p.m. the party started on a field trip through the French Lick valley for the purpose of visiting the numerous mineral springs, rock formations and hills which have been left as a result of valley erosion.

After dinner at the Windsor Hotel, the members and their guests assembled at the Christian Church for a brief business meeting. Following the business meeting, Prof. C. A. Malott, of Indiana University, gave a very interesting and instructive lecture on the geology of Lost River. By means of clear descriptions and excellent charts Prof. Malott also discussed the geology of the country that was to be visited on Friday.

Friday, May 12.

The party left the Windsor Hotel at 8:00 a.m. for Stamper's Creek in order to study this creek at the point where it becomes subterranean.

Lost River was next studied. It was first viewed as a rather large stream flowing over a rather flat limestone country. A few miles below, it was found to disappear by means of small sinks in the river bottom. The next stop was made at the first storm swallow-hole which, under moderate rainfall, takes care of all the water that does not disappear farther up the stream. The second storm-hole, which receives the overflow during severe rains, was also visited.

The party arrived at Wesley Chapel at noon, where a sumptuous chicken dinner was served. The early part of the afternoon was spent in Wesley Chapel Gulf, which is a collapsed sink of the Lost River subterranean channel.

On the way back to French Lick the party stopped at Orangeville, where Lost River once more rises to the surface.

After supper the evening was spent at the Windsor Hotel in making and renewing acquaintances.

Saturday, May 13.

Before starting home several of the company visited the "Gorge" about two miles southeast of French Lick for the purpose of studying the geological formations.

Those of the party who went by automobile to Bloomington greatly enjoyed a visit to the caves at Mitchell with Prof. and Mrs. Eigenmann.

Business Session.

French Lick, Indiana, May 11, 1922.

The members of the Academy assembled in the Christian Church, where the meeting was called to order at 7:30 p. m. by President F. M. Andrews.

The request of Prof. A. Richards, formerly of Wabash College, to be placed on the non-resident list was declined but it was voted that since he and Mrs. Richards did not desire to each carry active membership, that their names be made to read Dr. and Mrs. A. Richards and be considered as one membership.

A communication from Prof. Ehlers of the Michigan Academy was read. He extended an invitation to the Geological Section of the Indiana Academy to join them in their spring meeting.

Prof. Cogshall of the Membership Committee proposed the names of the following persons who were duly elected to membership:

Allee, W. N., 221 E. Fourth St., Bloomington.

Barnett, Horace L., Department of Geology, Indiana University, Bloomington.

Dean, Miss Grace, French Lick.

Pearson, Nathan E., Department of Zoology, Indiana University, Bloomington.

Senour, Frank C., 323 N. Grant St., Bloomington.

A letter was read from Dr. H. W. Wiley expressing his regret at not being able to attend the Spring Meeting.

President Andrews read a letter from Mrs. Frank Sheehan regarding the Dunes Summer Camp. He stated that several members of the University of Chicago staff were helping to promote this camp, which indicated that it was for educational and scientific purposes.

The following suggestions were made as to the possible place of holding the meeting next year: Dunes, Culver Military Academy and vicinity, Anderson, Richmond, Madison, lakes region of Steuben County. It was suggested that the Michigan Academy might wish to join us in a meeting if held in the lakes region.

Adjourned at 8:10 p. m.

F. M. Andrews,
President.

Walter N. Hess,
Secretary.

WINTER MEETING.

PROGRAM OF THE THIRTY-EIGHTH ANNUAL MEETING
OF
THE INDIANA ACADEMY OF SCIENCE
HELD AT
LINCOLN HOTEL, INDIANAPOLIS.
December 7 and 8, 1922.

PROGRAM COMMITTEE.

R. C. FRIESNER. H. L. BRUNER.
W. M. BLANCHARD.

DECEMBER 7, 1922.

8:00 p. m. Executive Committee Meeting.
Reports of Committees.

DECEMBER 8, 1922.

9:00- 9:30 a. m. General Business Meeting.
9:30-12:00 m. General Session.

Estimating the Comparative Richness of Indiana. Stephen S. Visher, Indiana University.

*A Photographic Study of Architectural Acoustics. (Illustrated.) Arthur L. Foley, Indiana University. (Published in The American Architect and Architectural Review, November 8, 1922.)

Francis Galton, Life and Work. Robert Hessler, Indianapolis.

The Paleolithic Stone Age in Indiana. (Illustrated.) S. Frank Balcom, Indianapolis.

Recent Archeological Discoveries in Jefferson County, Indiana. Glenn Culbertson, Hanover College.

*The Smog Problem. Robert Hessler, Indianapolis.

Life and Mind. Robert W. McBride, Indianapolis.

*The Scientific Work of the Conservation Commission. (By title.) Stanley Coulter, Purdue University.

The Southern Ute Indians of Pine River Valley, Colorado. (By title.) Albert B. Reagan, Cornfields, Ganado, Arizona.

*Indian Funerals. (By title.) Albert B. Reagan, Cornfields, Ganado, Arizona.

Twinkling Star. (By title.) Albert B. Reagan, Cornfields, Ganado, Arizona.

Frank Barbour Wynn: In Memoriam. Robert W. McBride, Indianapolis.

Alexander Smith: In Memoriam. R. E. Lyons, Indiana University.

Earl Jerome Grimes: In Memoriam. Harry F. Dietz, State Conservation Commission.

Address of the Retiring President: Some Problems in Plant Physiology. Frank M. Andrews, Indiana University.

1:30- 2:00 p. m. General Business Meeting.
2:00- 5:30 p. m. Sectional Meetings.

* Papers starred (*) not published in this Proceedings.

GEOLOGY AND GEOGRAPHY.

History of the Lakes near Laporte, Indiana. William Motier Tucker, Indiana University.

*Mineral Resources of Indiana. W. N. Logan, Indiana University.

Goniobasis livescens Menke, a Pleistocene Shell in Furnessville Blowout, Dunes of Porter County. (Illustrated.) Marcus W. Lyon, Jr., South Bend.

*Valley-Heads and Sheet-Wash Erosion. Clyde A. Malott, Indiana University.

*The Role of Sheet-Wash in Erosion. Clyde A. Malott, Indiana University.

A Review of the Present Knowledge of Fossil Scorpions with the Description of a new species from the Pottsville Formation of Clay County, Indiana. (By title.) John Irvin Moore, Owensville.

Some Contrasts between Geographic Regions in Indiana. Stephen S. Visher, Indiana University.

Abandoned Channels in Randolph and Delaware Counties, Indiana. Frederick J. Breeze, Indiana State Normal School, Eastern Division.

*The Muncie Esker. Frederick J. Breeze, Indiana State Normal School, Eastern Division.

*The Entrenched Meanders and Associated Terraces in the Muscatatuck River, near Vernon, Indiana. Burton J. Malott, Technical High School, Indianapolis.

†A new Pleistocene Gastropod from Maryland. (By title.) Ernest Rice Smith, DePauw University.

Archeology in Posey and Vanderburg Counties, Indiana. Andrew J. Bigney, Evansville College.

CHEMISTRY AND PHYSICS.

Chemistry.

Qualitative Analysis—Tin Group. Ralph W. Hufferd, DePauw University.

Qualitative Analysis—Iron Group. Ralph W. Hufferd, DePauw University.

*The Normal System in Quantitative Analysis. E. G. Mahin, Purdue University.

The Effect of Non-Metallic Impurities on Cementite Distribution in Steel. (Illustrated.) G. B. Wilson, Purdue University.

*Some Toxic Soils of Indiana. (Illustrated.) R. H. Carr, Purdue University. (Published under the title "Manganese, Aluminum, and Iron Ratio as Related to Soil Toxicity," in Journal of Industrial and Chemical Engineering, June, 1923.)

A Study of, and a Modified Method for, Vogel's Reaction for Cobalt. F. J. Allen and A. R. Middleton, Purdue University.

Thiocyanotocobaltous Acid and Its Alkali Salts. F. J. Allen and A. R. Middleton, Purdue University.

---

* Papers starred (*) not published in this proceedings.

† Another title substituted in this Proceedings.

Evaporation of Solutions in Burettes. M. G. Mellon, Purdue University.

The Use of Solutions of Inorganic Salts as Permanent Color Standards, M. G. Mellon, Purdue University.

An Improved Murexide Test for Teaching Purposes. Samuel E. Earp, Indianapolis.

Fog Formation in Air Which Has Passed Through a Silent Discharge. (Illustrated). F. O. Anderegg and K. B. McEachron, Purdue University.

A Type of Silent Discharge Involving Catalysis. (Illustrated.) F. O. Anderegg and E. H. Bowers, Purdue University.

A Further Study of Pressure Reversals in the Corona Discharge. (Illustrated.) F. O. Anderegg, Purdue University.

*The Peculiar Properties of Water in light of its Molecular Structure. (Illustrated.) F. O. Anderegg, Purdue University.

Physics.

*Some Untenable Acoustic Theories. Arthur L. Foley, Indiana University. (Published under title "A Photographic Study of Sound Pulses between Curved Walls and Sound Amplification by Horns," in Physical Review, S.S., vol. 20, no. 6, December, 1922.)

Improved Designs of Sound Condensers. (Illustrated.) Arthur L. Foley, Indiana University.

Locomotive Whistle Experiments. (Illustrated). Arthur L. Foley, Indiana University.

*Energy Losses in Commercial Hammers. (Illustrated.) Edwin Morrison, Michigan Agricultural College.

*Scattering of Light by Small Particles. (Illustrated.) Edwin Morrison, Michigan Agricultural College.

*Spectrum of Phosphorescent Mercury. (Illustrated.) E. K. Chapman, Wabash College.

A Method of Measuring the Amplification of Two or More Stage Amplifiers. (Illustrated.) R. R. Ramsey, Indiana University.

A Method of Securing Accurate High Frequency Standard. R. R. Ramsey, Indiana University.

An Oscillographic Study of an Induction Coil with High Frequency Load. F. O. Anderegg and K. B. McEachron, Purdue University.

An Investigation of the Foley Telephone Mouthpiece. (Illustrated.) James E. Brock, Sweetser.

*Diffraction of Light through Circular Openings. (Illustrated.) Mason E. Hufford, Indiana University.

BIOLOGICAL SCIENCES.

Zoology.

*Some Genes Modifying Crossing-Over. F. Payne, Indiana University.

The Occurrence of Secondary Parasitism in the Frog. (By title.) George Zebrowski, Purdue University.

* Papers starred (*) not published in this proceedings.

*Relation of Insects to Human Life and to the other Sciences. John J. Davis, Purdue University.

*Content of First Course in Zoölogy. R. A. Gantz, Indiana State Normal School, Eastern Division.

Notes on Mammals of the Dune Region of Porter County, Indiana. (Illustrated.) Marcus W. Lyon, Jr., South Bend.

*Notes on the Termites of Indiana. (Illustrated.) Harry F. Dietz, Indianapolis.

*Complement-deficient Guinea-pig Serum. (By title.) Roscoe R. Hyde, Johns Hopkins University. (To be published in American Journal of Hygiene, 1923.)

Reactions to Light and Photoreceptors of *Lumbricus terrestris*. Walter N. Hess, DePauw University.

Chromosomal Variations in the Earwig, *Anisolabris annuleipes* Lucas. W. P. Morgan, Indiana Central College.

A Hygrothermograph Puzzle. W. H. Larrimer, U.S. Entomological Laboratory, West Lafayette.

*A Study of the Virginia Opossum. W. H. Sheak, Ijamsville.

Bacteriology.

Nagana (*Trypanosoma brucei*): The Course of the Disease in Laboratory Animals when Injected with Cultures Grown *in vivo* and *in vitro*. Charles A. Behrens, Purdue University.

The Use of Clark and Lubs Indicators for the Detection of Acid Production by Colon-Typhoid Group. P. A. Tetrault, Purdue University.

Soil Bacterial Types and Green Manuring. I. L. Baldwin, Purdue University.

A Simple Method of Determining the Thermal Death-point. James B. Kendrick and Max W. Gardner, Purdue Agricultural Experiment Station.

Botany.

Further Notes on the Unusual Stipules of *Acer nigrum* Michx. Flora Anderson, Indiana University.

†Unusual Branching in Cladophora. Flora Anderson, Indiana University.

Plants New to Indiana. XI. C. C. Deam, Bluffton.

*Attack of Fungi on the Lids of Water Culture Jars. F. M. Andrews, Indiana University.

The Effect of Pressure on Seedlings. F. M. Andrews, Indiana University.

The Convolvulaceae of Indiana. Truman G. Yuncker, DePauw University.

Recent Indiana Weeds. Albert A. Hansen, Purdue Agricultural Experiment Station.

Wild Corn as a Weed Problem in Indiana. Albert A. Hansen, Purdue Agricultural Experiment Station.

* Papers starred (*) not published in this proceedings.
† Another title substituted in this Proceedings.

*List of Indiana Plants, Chiefly from Putnam County. Collected 1911-1915 by Earl Jerome Grimes. (By title.) Mrs. Eileen W. Grimes, University of Michigan.

*Polyembryony in Species of Osmunda and Dryopteris. David M. Mottier, Indiana University.

Embryonic Selection in Certain Nut Bearing Pines. David M. Mottier, Indiana University.

Phytophthora Rot of Tomato, Eggplant and Pepper. James B. Kendrick, Purdue Agricultural Experiment Station.

Differences in the Susceptibility of Clover to Powdery Mildew. (Illustrated.) E. B. Mains, Purdue Agricultural Experiment Station.

Notes on Microtechnique. II. M. S. Markle, Earlham College.

Chloroplasts of *Martynia fragrans*. F. M. Andrews, Indiana University.

Quantitative Estimation of Aeration in Leaves. F. M. Andrews, Indiana University.

*Indiana Plant Diseases, 1922. (Illustrated.) Max W. Gardner, Purdue Agricultural Experiment Station.

†Indiana Fungi. VII. J. M. Van Hook, Indiana University.

*Relation of Barberry to Stem Rust of Wheat: Results of Indiana Survey. (Illustrated.) K. E. Beeson (introduced by H. S. Jackson), Purdue Agricultural Experiment Station.

An Unusual Iris. F. M. Andrews, Indiana University.

Second Blooming of a Snowball Bush in the Same Year. F. M. Andrews, Indiana University.

The Present Status of the Hot Water Treatment of Wheat in Indiana. Charles Gregory, Purdue Agricultural Experiment Station.

Onion Smut in Indiana. Charles Gregory, Purdue Agricultural Experiment Station.

Plants of White County. V. Louis F. Heimlich, Purdue University.

*The Microscopy of Flour. (By title.) Harold E. Turley, American Institute of Baking, Chicago, Ill. (Published in Baking Technology, November 15, 1922.)

6:00- 8:00 p. m. Annual Academy Dinner.

8:00-10:00 p. m. General Session.

*The Fundamental Principles of Radio Transmission and Reception. (Illustrated.) R. R. Ramsey, Indiana University.

*The Scientific Propagation of Black Bass in Ponds as Conducted at the Riverside Station in Indianapolis. (Two reels motion pictures.) G. M. Mannfeld, State Conservation Commission.

*The Artificial Propagation of Pike-Perch. (One reel motion pictures.) G. M. Mannfeld, State Conservation Commission.

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* Papers starred (*) not published in this proceedings.

† Another title substituted in this Proceedings.

MINUTES OF BUSINESS SESSION.

LINCOLN HOTEL, INDIANAPOLIS.

MEETING OF THE EXECUTIVE COMMITTEE.

December 7, 1922.

The Executive Committee was called to order at 8:15 p. m. in Parlor E, by President F. M. Andrews. The following members were present: F. M. Andrews, C. A. Behrens, W. M. Blanchard, F. J. Breeze, W. A. Cogshall, Stanley Coulter, Glenn Culbertson, H. F. Dietz, H. E. Enders, A. L. Foley, R. C. Friesner, W. N. Hess, R. W. McBride, D. M. Mottier, J. P. Naylor, F. Payne, E. B. Williamson, J. S. Wright.

The minutes of the last meeting of the Executive Committee were read and approved.

Committee reports were considered as follows:

Committee on Program.

Chairman R. C. Friesner presented the printed program of 95 titles to be read at the general sessions tomorrow. He called attention to the crowded condition of the program and that each branch of science had sufficient number of papers for a section of its own. A letter from the Ohio Academy reiterated its desire to hold a joint meeting with the Indiana Academy in the near future. Professor Friesner stated that there had been some criticism because the programs were mailed out early. He explained that the printed programs contained all titles received up to November 9 and that they were mailed out on November 17. He further stated that the supplementary list contained all titles received up to and including December 7.

Professor Friesner asked for an expression from the Academy concerning the advisability of having the meeting next year at one of the educational institutions. After some discussion Judge McBride moved that the Executive Committee select the place of meeting instead of the Program Committee. Passed.

Committee on Membership.

Mr. Dietz reported 51 new names to be presented at the meeting tomorrow. He spoke of the fine co-operation received from all who were asked to aid in securing new members.

Committee on Biological Survey.

No report.

Committee on Distribution of Proceedings.

Professor Hess reported that the 1921 Proceedings were mailed out in August. He requested help in keeping the mailing list correct and asked all members who did not receive their copy of the Proceedings to advise him.

Committee on Relation of the Academy to the State.

Judge Robert W. McBride reported that the present cuts in appropriations would not affect the funds of the Academy.

Report of the Treasurer.

Balance on hand December 1, 1921	$299 16
Dues collected during the year	385 00
Total	$684 16
Total expenditures	351 59
Balance in treasury December 1, 1922	$332 57

(The treasurer's account does not include the funds appropriated by the State for the publication of the Proceedings. Editor.)

Committee on Auditing.

Mr. E. B. Williamson reported on the accuracy of the treasurer's report. A motion authorizing the transfer of $100.00 from the treasury to the trustees of the Research Endowment Fund was introduced by Professor Blanchard. Passed. This motion was later rescinded.

Committee on Publication of Proceedings.

Chairman F. Payne stated that it had been demonstrated as possible to secure prompt publication of the Proceedings. He stated that we still owed the Fort Wayne Printing Company about $150.00 on an old account. After some discussion it was moved and passed that this sum be paid from the surplus funds of the State which were left from the publication of the last Proceedings. This motion was later rescinded.

Advisory Council.

Chairman John S. Wright suggested we pay the account owing the Fort Wayne Printing Company from the funds of our own treasury. It was moved by Judge McBride that we reconsider the motion to transfer $100.00 to the trustees of the Endowment Fund, and pay the Fort Wayne Printing Company account from the treasury of the Academy. On motion the money was returned to the treasury and the Fort Wayne Printing Company bill ordered paid.

Committee on Research.

Professor J. P. Naylor announced that the Committee on Research was appointed without duties. In explanation Mr. Wright stated that the committee would probably be inactive until sufficient funds were available for research work.

Committee on Academy Foundation.

No report.

Committee on Archeological Survey.

No report.

Committee on Indexing Proceedings.

Mr. Dietz stated that there was not sufficient money at the disposal of the State Library to do this work. He suggested that the work be divided up into its natural divisions of Botany, Zoölogy, Chemistry, etc., and assigned to individuals. It was moved by Dr. Stanley Coulter that this plan be followed provided that capable men can be found who will undertake the work. Motion passed.

General Business.

Dr. A. L. Foley called attention of the Academy to the fact that, if we are to do anything about choosing a place for our meetings next year, it must be done tonight. After brief discussion it was moved by Judge McBride and passed that the incoming President, Secretary, and Treasurer be authorized to choose the place for our next winter meeting.

Professor Glenn Culbertson invited the Academy to Hanover, but stated that he thought the first meeting away from Indianapolis might better be held at some more centrally located point.

President Andrews brought up the question of an Academy seal. Mr. Wright advised the purchase of a seal and suggested the use of membership certificates. After some discussion it was moved that a committee, with power to act, be appointed to consider the purchase of a seal and the adoption of membership certificates. Passed. The following committee was appointed: Dr. Stanley Coulter, Dr. A. L. Foley, Mr. John S. Wright.

Adjourned 9:45 p. m.

MINUTES OF GENERAL SESSION.

9:00 a. m., December 9, 1922.

Business Session.

The session was called to order by President Andrews. The minutes of the Executive Committee were read and approved.

The Membership Committee proposed the following named persons for membership: On motion they were duly elected.

Auble, Robert N., 409 Wolcott St., Indianapolis.
Beecher, Alva, Crawfordsville, Ind.
Beeson, K. E., 427 State St., West Lafayette.
Bell, Alva Marie, 511 Smith Ave., Bloomington.
Berg, George F. Jr., 3518 Balsam Ave., Indianapolis.
Bolen, Homer R., 314 S. Grant St., Bloomington.
Book, William F., 516 N. Fess Ave., Bloomington.
Boots, Edwin B., 125 N. 6th St., W. Terre Haute.
Brock, James E., Sweetser, Ind.
Brosey, Charles L., 766 West Drive, Woodruff Place, Indianapolis.
Bushnell, T. M., Agr. Expt. Sta., West Lafayette.
Chitty, Ethel, Indiana State Normal, Muncie.
Clay, Mrs. Celia, 320 N. State St. Kendallville.
Cox, C. F., 364 N. Audubon Ave., Indianapolis.
Davis, Charles, 217 Sylvia St., West Lafayette.
Doan, Richard L., 802 E. Third St., Bloomington.
Donaghy, Frederick, Indiana State Normal, Terre Haute.
Dugan, Elizabeth, 717 N. Tremont St., Indianapolis.
Eaton, Dunwald L., Indiana Central College, Indianapolis.

Esarey, Ralph E., 924 Atwater St., Bloomington.
Gregory, Charles T., 1022 First St., W. Lafayette.
Hills, Donald H., 2127 Talbott St., Indianapolis.
Hoffer, George N., 434 Littleton St., W. Lafayette.
Hoffman, A. C., 920 East Drive, Woodruff Place, Indianapolis.
Kennedy, Clarence H., Ohio State Univ., Dept. of Zoöl., Columbus, O.
Kiester, Jackson A., 300 S. Green St., Crawfordsville.
Klipinger, Walter C., 2234 Park Ave., Indianapolis.
Knecht, Christian, 207 N. Dunn St., Bloomington.
Koehring, Vera, Butler College, Indianapolis.
Kurtz, J. M., Goshen College, Goshen.
Lanham, Bess, 610 E. Wabash Ave., Crawfordsville.
Lyon, Marcus Ward, Jr., 214 LaPorte Ave., South Bend.
McDonald, Clinton C., 415 S. Dunn St., Bloomington.
Madenwald, Frederick A., 621 E. 10th St., Bloomington.
Malott, Ruth Boyd, Butler Ave., Indianapolis.
Mannfeld, George N., 1235 Central Ave., Indianapolis.
Martin, Essie S., 134 N. Drexel St., Indianapolis.
Martin, Mrs. Viva Dutton, 134 N. Drexel St., Indianapolis.
Michael, Lyle Jordan, Indiana Central College, Indianapolis..
Montgomery, Basil E., Poseyville Ind.
Moore, John Irwin, Owensville.
Moorhead, John G., 124 DeHart St., W. Lafayette.
Mullendore, Naomi, Franklin.
Noble, Willis Bernard, Box 95, W. Lafayette.
Osbun, Clifford Leroy, 201 Russel St., W. Lafayette.
Payne, Mary, South Downey Ave., Indianapolis.
Pitkin, Edward M., 519 N. College St., Bloomington.
Protchard, R. V., Butler College, Indianapolis.
Roberts, Harry John, Route A, Lafayette.
Robertson, Ray B., 702 Evergreen St., W. Lafayette.
Smith, Lee T., R. F. D. No. 7, Bloomington.
Stirrett, George M., 521 State St., W. Lafayette.
Strickler, Alvin, Evansville College, Evansville.
Tasker, Roy C., 612 Anderson St., Greencastle.
Taylor, George O., 502 S. Sluss Ave., Bloomington.
Teeters, Charles E., 346 N. Audubon Ave., Indianapolis.
Ward, Mary Mallory, 405 E. William St., Kendallville.
Wilson, E. R., 2830 E. Vermont St., Indianapolis.
Young, Herman, 602 N. College St., Bloomington.
Zierer, Clifford M., Geography Dept., Indiana University, Bloomington.

Mr. Demarchus Brown, State Librarian, announced that there were, in the State Library, about 5,500 separate items belonging to the Academy. He stated that the library was behind in binding and that many of the foreign exchanges were only beginning to come in.

Mr. Brown called the attention of the Academy to the fact that the general public did not use the exchanges of the Academy as it is a rule of the Academy that such publications cannot be loaned except

to Academy members. After brief discussion Professor Cogshall moved, and it was passed, that the loaning of the exchanges of the Academy be left to the discretion of the State Librarian.

Mr. Brown stated, in conclusion, that the State Library was very seriously in need of more funds, and he urged the members to advise their legislators of the library needs.

Mr. Butler expressed the appreciation of the Academy for the work of Mr. Brown and his associates, and strongly urged the co-operation of each member in securing, through legislation, more funds for the use of the State Library.

Professor Enders, as chairman of the Committee on Nominations, recommended the election of the following to fellowship. Adopted: Ralph H. Carr, Harry F. Dietz, Edward G. Mahin, Paul Weatherwax.

Chairman Enders, also announced the following nominations for officers for 1923:

President	C. A. Behrens, Lafayette
Vice-president	F. Payne, Bloomington
Secretary	W. N. Hess, Greencastle
Assistant Secretary	Flora Anderson, Bloomington
Treasurer	W. M. Blanchard, Greencastle
Editor	J. J. Davis, Lafayette
Press Secretary	H. F. Dietz, Indianapolis

On motion, the above named officers were elected.

Professor Enders requested that the list of the former officers of the Academy be printed each year in the Proceedings.

It was moved that the secretary be instructed to write a letter expressing our appreciation to the management of the Lincoln Hotel for the courtesies shown. Motion passed.

Professor W. M. Blanchard, in behalf of the science departments of DePauw University, invited the Academy to hold its next winter meeting at Greencastle. It was moved by Dr. Stanley Coulter that this invitation be accepted. Motion carried.

Professor J. P. Naylor introduced the following resolution which was acted upon favorably: Resolved, "That hereafter it be the sense of the Academy that no member shall occupy more than ten minutes in the presentation of a paper or abstract, except that the president's address may occupy thirty minutes. The president, or person appointed by him, shall notify the speaker when he has exhausted the time, and he can continue only by vote of the assembly to extend the time."

Dr. W. N. Logan reported for the Archeological Survey that work was being continued on the county maps, which were for the purpose of indexing archeological material.

Adjourned for sectional meetings at 2:15 p. m.

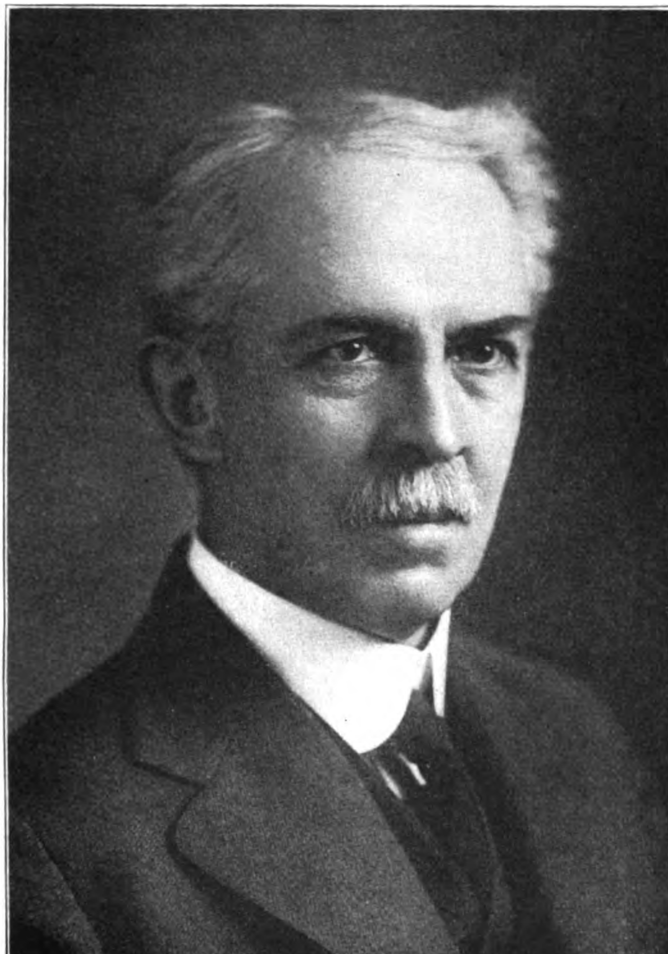
Sixty-one members and guests participated in the dinner at 6:00 p. m. At the close of the dinner the members of the Academy and their friends assembled in the Travertine room for the evening program.

The evening program included an illustrated lecture by Professor R. R. Ramsey of Indiana University, on "The Fundamental Principles of Radio Transmission and Reception". This was followed by several motion pictures, presented by Mr. G. M. Mannfeld, on the propagation of black bass and pike-perch.

At 10:30 p. m. the 38th annual meeting of the Indiana Academy of Science closed.

F. M. ANDREWS,
President.

WALTER N. HESS,
Secretary.



Frank Barbour Wynn
1860-1922

"Proc. 38th Meeting, 1922 (1923)."

FRANK BARBOUR WYNN.

Brookville, Indiana. Mt. Siyeh, Montana.
May 28, 1860. July 27, 1922.

Since the last meeting of the Academy we have lost one of our most useful and most distinguished members, in the passing of Dr. Frank Barbour Wynn. He became a member of the Academy at the annual meeting in 1916, and while he contributed few papers he was prompt in his attendance and helpful and practical in his suggestions. His smiling countenance and his cheerful voice will be sorely missed by all. In his varied activities he represented the highest type of American manhood.

Frank Barbour Wynn was a native of Indiana, his birthplace, Brookville, Franklin County, Indiana, the same as that of the Indiana Academy of Science. He was born May 28, 1860. He graduated at DePauw University in 1883, with the degree of A. B. This institution, in 1886, granted him the degree of Master of Arts, and in 1922, just a month prior to his death, they conferred upon him the honorary degree of Doctor of Science. In 1885 he was graduated from the Miami Medical College, at Cincinnati, Ohio, with the degree of M. D.

He was assistant physician in the Ohio Insane Asylum, at Dayton, Ohio, from 1886 to 1888, and in 1891 he was on the medical staff of the Northern Indiana Hospital for the Insane, at Logansport. In the years 1892 and 1893 he studied in the hospitals and other institutions of New York, London, Paris, Berlin, and Vienna, and then located for the practice of his profession in Indianapolis. Since that time his activities have been so varied and of such value that no history of Indiana, covering the period from 1900 to the date of his death, can be fully and truthfully written without frequent mention of them. He was the president of the State Historical Commission, and bore a leading part in the centennial celebration of Indiana's admission to statehood. He was a valued and useful member of the Indiana Historical Society, Indianapolis Chamber of Commerce, and was chairman of the State Park Board. He was a vice-president of the American Medical Association in 1921, president of the Indiana Medical Association in 1914 and 1915, president of the Mississippi Valley Medical Association in 1920, and a fellow of the American College of Physicians. He was held in highest esteem by all his confreres. He was president of the recently organized Lincoln Memorial Association. From 1895 to the date of his death he held the chair of Medical Diagnosis in the Indiana School of Medicine. A lover of nature, he was an active member of the Indiana Audubon Society, and president of the Indiana Nature Study Club. He was also a member of the committee to Collect Data on the Archeology of Indiana. He was not a seeker after preferment. Preferment sought him, and it ever came as a recognition of special fitness. He not only occupied the several positions above enumerated, but what is far more important, he filled each and all of them acceptably and ably. He was a peculiar combination of versatility, profound and thoroughgoing ability, and a genial and loving personality.

For many years he had spent much of his vacation periods in the mountains and in mountain climbing. He had climbed many of the great mountains of Switzerland and of America and was president of the American Alpine Club. It was while engaged in his favorite recreation, scaling Mt. Siyeh, in Glacier National Park, that he met death.

In his religious affiliations he was a member of the Meridian Street Methodist Episcopal Church, in Indianapolis. In his social and professional life, while he was positive and forceful in action, he was always courteous, kindly and considerate of the rights and of the feelings of others. Clean in thought, clean in speech, he was an honorable, an upright, and a Christian gentleman, with all which that title implies.

Frank B. Wynn was a contributor to periodicals and newspapers, writing popular, fascinating articles on mountain trips, etc. He was a compiler of songs used by the Nature Study Club. The booklet "Suggestive Plans, Indiana's Centennial Celebration, Nineteen Sixteen" was in large part the result of his work and interest.

Short non-technical papers included "The Mountain Queen" (dedicated to the Mazamas, July 4, 1915), "The Campfire", "Hail to Indiana", "My Boy", "Sleep", and others.

His more technical articles are in part, at least, as follows:

LIST OF PAPERS BY FRANK B. WYNN.

Some sanitary questions concerning tuberculosis. Trans. Ind. St. Med. Soc., 1896, p. 149.

Oral lesions of syphilis in relation to the public health. Trans. Ind. St. Med. Soc. 1898, p. 331.

Two cases of splenomedullary leukemia with specimens. Trans. Ind. St. Med. Soc. 1899, p. 154.

Report of committee on pathology. Trans. Ind. St. Med. Soc. 1899, p. 429.

Report of committee on pathology. Trans. Ind. St. Med. Soc. 1901, p. 542.

Report of committee on pathology of the Indiana State Medical Soc. 1902, p. 375.

The X-ray in the treatment of skin diseases. Trans. Ind. St. Med. Soc. 1903, p. 201.

Report on scientific exhibit, Indiana State Medical Society. Trans. Ind. St. Med. Soc. 1903, p. 315.

Human immunity in tuberculosis. Colo. St. Med. Jr. vol. 10, p. 116, 1904.

Digitalis and Cardiac Hypertrophy. Jr. Amer. Med. Assn. vol. 43, p. 164, 1904.

Report on the scientific exhibit. Jr. Amer. Med. Assn. vol. 43, p. 828, 1904.

Diagnosis and treatment of incipient skin cancer. Lancet-Clinic, vol. 55, p. 429, 1905.

Report on pathological exhibit. Trans. Ind. St. Med. Soc. 1905, p. 474.

Plexiform Neurofibroma. Jr. Amer. Med. Assn. vol. 46, p. 500, 1906.

X-ray treatment of skin tuberculosis. Amer. Jr. Derm. and Genito-Urinary Dis. vol. 10, p. 111, 1906.

Acetanilid poisoning. Jr. Amer. Med. Assn. vol. 49, p. 1037, 1907.

Report of a series of Leucemic cases, with brief comments on the symptomatology and treatment. Jr. Ind. Med. Assn. vol. 1, p. 58, 1908.

Tuberculosis exhibit and cabinet. Jr. Amer. Med. Assn. vol. 53, p. 946, 1909.

The psychic element in the causation and cure of disease. Jr. Ind. St. Med. Assn., vol. 2, p. 515, 1909.

Public health exhibits for permanent installation. Jr. Amer. Med. Assn. vol. 57, p. 1282, 1911.

Report of cases treated by "606". Jr. Ind. St. Med. Assn. vol. 4, p. 293, 1911.

Public health exhibits. Jr. Amer. Med. Assn. vol. 56, p. 294, 1913.

Our association and its activities. Some suggestions and plans for the success of the next annual meeting. Jr. Ind. St. Med. Assn. vol. 8, p. 1, 1915.

The necessity of co-ordinating methods in the definite diagnosis of pulmonary tuberculosis lesions. Jr. Ind. St. Med. Assn. vol. 10, p. 15, 1917.

Psychic factors in temperature, etc. Jr. Amer. Med. Assn. vol. 73, p. 31, July 5, 1919.

Renal tuberculosis. Its early recognition and management from the viewpoint of the internist. Jr. Ind. St. Med. Assn. vol. 14, p. 33, 1921.

The ten commandments of medical ethics. Indianapolis, 1922.

ROBERT W. McBRIDE.

ALEXANDER SMITH.

Edinburgh, Scotland, 1865. Edinburgh, Scotland, Sept. 9, 1922.

From Edinburgh, Scotland, his birthplace, comes the announcement of the death of Professor Alexander Smith, a distinguished and honored member of our Academy, lately head of the department of chemistry at Columbia University in New York.

About three years ago while addressing a class he was stricken with a fainting spell caused by the fatal malady. Shortly afterward he underwent operation for tumor of the stomach. The hoped for recovery with restoration to health did not come. He suffered intense depression and was an invalid from that time on. While the termination, on September 9, 1922, of the long and insidious illness which clouded his latter days was not unexpected, his loss is a heavy one for chemistry.

Alexander Smith, son of a well known musician of Edinburgh, had the advantage of the best chemical training available in Europe during his student days. He received the degree B.Sc. at the University of Edinburgh in 1886; the Ph.D. degree at the University of Munich, as a student of the master organic chemist, Adolph Von Baeyer, in 1889, and during 1890 served as assistant in chemistry in the University of Edinburgh.

Thus splendidly equipped for the work of a teacher of chemistry Smith came in the fall of 1891 to the professorship of chemistry in Wabash College at Crawfordsville, Indiana. He soon became identified with the science organizations of the State and was elected to membership in the Indiana Academy of Science at the December meeting 1891. During the years following he contributed much to the success of the annual meetings of the Academy, especially in the chemistry-physics section, through forceful discussion and through presentation of papers concerning his researches on 1:3 and 1:4 di-ketones, syntheses by means of potassium cyanide, and the constitution of calomel vapor.

Alexander Smith was a gentleman of polished manner, pleasing address and striking personality. As those who knew him will recollect, his clear and sparkling eye constituted a very conspicuous and characteristic feature.

His election to Fellowship in the Academy occurred in 1893 and our records show that he remained active until 1908 when his name was placed on the non-resident list of members, he having been called from Wabash College to a professorship in the University of Chicago in 1894.

The bibliography contains a long list of titles of published researches and text books. The researches on sulphur and on vapor pressure in 1912 won for him the Keith Prize from the Royal Society of Edinburgh.

Smith's sphere of influence in chemistry was perhaps widest as a great teacher and as author of pre-eminent text-books, such as his "Introduction to General Inorganic Chemistry", "General Chemistry for Colleges", "A Laboratory Outline of General Chemistry", and others.

"Proc. 38th Meeting, 1922 (1923)."

These texts have had wide use in English speaking countries and most of them have been translated into German, Russian, Italian, Portuguese, Spanish, Chinese, and even into Urdu.

It was while serving as Director of General and Physical Chemistry in the University of Chicago that his teaching methods were chiefly developed. In fact, his career at Chicago was brilliant and intensely active. In addition to teaching and administrative work within his department he served as Dean of the Junior College of Science and possessed energy in reserve to continue investigative work.

In 1911 he was called to Columbia University as head of the department of chemistry which he proceeded to reorganize and expand in a fundamental way. With his characteristic overflowing enthusiasm, industry and vitality he continued active until forced by illness to desist.

Alexander Smith's career was a brilliant one but all too short. American chemical history presents the names of but few chemists of such attainment in a generation.

LIST OF PAPERS BY ALEXANDER SMITH.

I. PUBLISHED INVESTIGATIONS.

(a) Organic Chemistry.

1. Thesis, Ueber 1, 3-Diketone. Munich, 1889. Beiträge zur Kenntniss der 1, 3-Diketone [with Prof. Claisen]. Liebig's Annalen, *277* (1893), 184-206.
2. On Desylacetophenone. Journal of the Chemical Society, *57* (1890), 643-652.
3. Ueber Condensation mittelst Cyankalium. Berichte der deutschen chemischen Gesellschaft, *26* (1892), 60-65.
4. Ueber die Condensation von Aceton mit Benzoin mittels Cyankalium. Berichte der deutschen chemischen Gesellschaft, *26* (1892), 65-71.
5. Two Stereo-isomeric Hydrazones of Benzoin [with J. H. Ransom]. Royal Society Edin., Proceedings, 1894, pp. 201-202; American Chemical Journal, *16* (1894), 108-115.
6. Die Einwirkung von Hydrazin und von Phenylhydrazin auf 1, 4-Diketone. Liebig's Annalen, *289* (1896), 310-337.
7. Condensation with Benzoin by Means of Sodium Ethylate [Thesis of J. B. Garner]. University of Chicago Press, 1897.
8. On the Phenylhydrazones of Benzoin. American Chemical Journal, *22* (1899), 198-207.
9. On Potassium Cyanide as a Condensing Agent. American Chemical Journal, *22* (1899), 249-256.
10. Notizen ueber die Einwirkung von Phenylhydrazin auf einige 1, 4-Diketone [with H. N. McCoy]. Berichte der deutschen chemischen Gesellschaft, *35* (1902), 2169-2171.

(b) Inorganic and Physical Chemistry.

11. Amorphous Sulphur and Its Relation to the Freezing Point of Liquid Sulphur [with W. B. Holmes]. Royal Society Edin., Proceedings, 1902, pp. 290-301; Decennial Publications of the University of Chicago, IX; Zeitschrift für Physikalische Chemie, *42* (1903), 469-480.
12. On Two Liquid States of Sulphur, S_μ and S_λ, and Their Transition Point [with W. B. Holmes and E. S. Hall]. Royal Society Edin., Proceedings, 1905, 588-589; Zeitschrift für Physikalische Chemie, *52*, 602-625.
13. The Nature of the Amorphous Sulphur, and Contributions to the Study of the Influence of Foreign Bodies on the Phenomena of Supercooling Observed When Melted Sulphur is Suddenly Chilled [with W. B. Holmes]. Royal Society Edin., Proceedings, 1905, 590-592; Berichte der deutschen chemischen Gesellschaft, *35* (1902), 2992-2994; Zeitschrift für Physikalische Chemie, *54*, 257-293.
14. Further Study of the Two Forms of Liquid Sulphur as Dynamic Isomers [with C. M. Carson]. Royal Society Edin., Proceedings, 1906, 352-356; Zeitschrift für Physikalische Chemie, *57*, 689-717.

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III. ADDRESSES.

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IV. REVIEWS.

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ROBERT EDWARD LYONS,
Indiana University.

EARL JEROME GRIMES.

Russellville, Indiana, January 15, 1893. — Williamsburg, Virginia. December 15, 1921.

It seems to us, who cannot comprehend, that the most tragic irony of fate is for a young man to step into the Great Unknown just as he is beginning to realize his life's ambitions after conscientious and tireless effort to reach that goal. Thus came the untimely death of one of our younger members, Earl Jerome Grimes, December 15, 1921, at Williamsburg, Virginia.

Earl Jerome Grimes was born at Russellville, Indiana, January 15, 1893, the son of Charles F. and Izzie Anderson Grimes. To his parents he owed his simplicity of taste, his integrity, and his directness of speech as well as manner.

Even while in the grammar schools of the town of his birth he came under the influence of two of the members of this Academy, W. S. Blatchley and Charles C. Deam. In C. T. Malan, superintendent of the Russellville Schools, Mr. Grimes had a friend and confidant to whom he often presented the problems that arose in the early part of his career.

By the time he graduated from high school, in 1911, he had prepared a noteworthy collection of the flowering plants of Putnam County, as well as collections of reptiles, bird eggs and insects. Through his communion with the out-of-doors and through the help and encouragement given by those who appreciated the promise Mr. Grimes held, he developed into a keen and accurate observer, as well as a precise technician.

On graduating from high school, Mr. Grimes was forced to temporarily lay aside his ambition to go to college because of failing eyesight. Therefore, he entered the employment of the Department of Geology of the State of Indiana. Here, for two years, he was engaged in soil surveys conducted by that Department in co-operation with the Federal Bureau of Soils. In 1914, having accumulated sufficient funds by frugal living, and with his eyes improved, he entered Purdue University. Intermittently during the period from 1914 to February, 1916, he worked for the Federal Bureau of Soils and then entered the University of Illinois. Here, with the exception of the summer of 1917, he worked continuously until his graduation in 1918. For the excellence of his work at Illinois, Mr. Grimes was awarded "Final Honors", "Special Honors in Agriculture" and was elected to Sigma Xi.

May 28, 1918, a few days before graduation, Grimes enlisted in the army, going to Camp Taylor, Kentucky, two weeks later. He was commissioned second lieutenant of infantry August 26, and was selected for immediate foreign service. In September he sailed for France with the 84th Division. On the way across he contracted influenza which prevented his being sent to the front.

After the Armistice was signed he was made instructor in agriculture in the United States Army School at Le Mans. Later he went to

London as a United States Army Student at the Imperial College of the University of London. There he spent four months, and also did some work at the Rothamsted Experiment Station.

June 26, 1919, he married Miss Eileen Jessie Whitehead, also a botanist and a member of the graduating class of the University of London.

Returning to America in July, Mr. Grimes was honorably discharged from the army in August and soon after was appointed Associate Professor of Botany in the College of William and Mary at Williamsburg, Virginia. Here, until the time of his death, he conducted courses in General Botany, Taxonomy, Bacteriology, Plant Physiology, Plant Pathology, and Soils. Even his spare time he put to use in the field and made what is perhaps the largest and most complete collection of Virginia plants ever gathered. With this collection he has left his characteristic full and accurate notes so that the material may readily be worked up for publication.

In addition to being a member of the Indiana Academy of Science, which he joined in 1908, Mr. Grimes was also a member of the American Association for the Advancement of Science, American Society of Bacteriologists, Sigma Xi, and a charter member of the Association of Virginia Biologists. In his honor the students of biology at the College of William and Mary have joined his name with that of a great botanical collector of colonial days as the name of the biological society Mr. Grimes helped found—The Clayton-Grimes Biological Club.

In his death there passed an inspiring and sympathetic teacher, a tireless worker, a keen and accurate observer, a great botanist in the making.

Patient, persistent and determined, his brief span of life was one of achievement despite obstacles. It serves as a means of awakening us to the possibilities of human power—an inspiration to effective exertion.

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HARRY F. DIETZ.

PRESIDENT'S ADDRESS.

SOME PROBLEMS OF PLANT PHYSIOLOGY.

F. M. ANDREWS, Indiana University.

In the present paper only a few of the many interesting and important problems of plant physiology can be mentioned. The time at my disposal forbids, for the most part, even the briefest outline of these much-needed investigations, and permits me to make little more than a mere enumeration. To be sure, many of these problems have been objects of research on different occasions and they have been investigated carefully from various points of view. The writer has studied and written contributions on many of these problems some of which will be referred to later.

As one attacks a problem he must cautiously feel his way as if in the dark, for that is his status for the most part, at the beginning. Step by step he can move forward if all goes well. Frequently he finds himself completely baffled from the very first and is compelled to retreat. This retreat, however, should not deter him but rather should act as a stimulus which will cause him to recharge the next time with more foresight and determination. After one such failure he must often adopt an entirely different line and point of attack, and marshal his forces in a new formation. Very often a difficult problem must be approached first from one angle and then from another in order to see where an entering wedge may be driven. Finally, after persistent, well generaled, and conscientious attacks an impression will finally begin to be made and when the first wall has crumbled, and the first trenches have been crossed the remainder of the resistances of the problem will often surrender more easily. Other problems, however, will only succumb or be conquered by a state of siege and this the writer declares after many attempts in the research field. It is therefore for the earnest research man a declaration of war in the cause of science. In this worthy procedure the physiologist as well as other scientists should ask no quarter and should give none. In some investigations he can bide his time, but often the nature of the problem surrounds him with conditions over which he has no control. He therefore may not be able to complete a problem at once or by continuous prosecution, but, like many an artist, must await the return of proper scenery or conditions from day to day or even sometimes from year to year with its sunlight, shadows, and colors in order that the advance may be made under the proper conditions.

The writer's aim and efforts have been to elucidate wherever and whenever possible those truths of nature which of themselves constitute sufficient reward. In many lines of research, no absolutely continuous line of attack on a problem can be predetermined. Therefore the investigation must proceed according to the manner in which the problem behaves and the way in which it reacts to the conditions that surround it. As none of the many problems have been exhausted all

"Proc. 38th Meeting, 1922 (1923)."

can be further studied with profit. It is often quite worth while to record one's failures as well as one's successes in an investigation. This is frequently valuable for guidance in further research.

Often what at first seemed to be of chief importance in a problem turns out to be of minor value in comparison with later developments. New points of view or new problems present themselves as he progresses with his problem and crowd upon his attention to such an extent that a limitless field for investigation sooner or later presents itself for solution. The writer realizes that work of enormous value has already been accomplished and that greater discoveries are in store for the future. With this view in mind he now ventures to mention a few at least of the problems in plant physiology for further study.

If we direct our attention to the root system of plants we find that this subject has by no means received the attention which its importance deserves, notwithstanding the large amount of study that its various phases have received. As a root grows older it gradually loses its ability to absorb water, which function is constantly relegated to the young roots. The rapidity, however, that marks this change and the specific modifications that occur both in cell walls and protoplasts are worthy of study. The well known cases of root contraction include a number of interesting lines of investigation. Since neither osmotic pressure nor the activity of secondary growth causes variation in root contraction in different plants, the question of the character of the active cells both as to elasticity and also localized transformation requires close attention (1, Bd. II p. 17).

A root of Faba will exert a pressure of from 300 to 400 grams and will grow in clay, where it meets a resistance of 100 to 120 grams, almost as rapidly as in water (2). The writer has recently found that root growth of seedlings is not stopped by a water pressure of 600 atmospheres and that, although the root is rendered transparent in a fraction of a minute, it recovers in a few days when replanted.

The statolith theory, ingenious as it is, requires confirmation notwithstanding the galaxy of able investigators who have made contributions in its behalf. Various attempts have been made to explain geotropism by chemical change, and this has created a field of special interest. **Němec found that the geotropic stimulus caused certain** changes in the protoplasm. Long ago Kraus (3) showed that the amount of sugar increased on the lower side of a horizontal stem while the acidity decreased and that later both sugar and acid decreased. Kraus (4) also states that the percentage of sugar is increased in active shoots that are continually shaken but this has been questioned. Czapek (5) opened up a field for investigation on the chemical side by proving the formation of homogentisinic acid by the oxidation of tyrosin that were geotropically stimulated.

The character of the soil is an object of more thorough study, particularly with regard to the needs of certain plants whose roots often undergo extensive development. Nobbe (6) has shown that the roots of a wheat plant will total a length of 500-600 meters, while the roots of a squash plant may attain 25 kilometers or 15⅝ miles. It may be

readily seen that scarcely any part of the soil will escape penetration by one or more rootlets. Many relationships, symbiotic and otherwise, in connection with the root system await solution as are also various problems connected with the methods and effects of aeration.

The direction and rate of movement of water through the cortical cells of the root to the fibro vascular bundles still requires elucidation (7, p. 84). Roots generally are thicker the higher they arise from a stem (8, p. 126) but become smaller and smaller as they ramify through the soil. Here their function is chiefly one of absorption as can be shown by aniline dyes (1, Bd. I p. 134).

The ability of certain plant parts to again put out new roots is well known. "A leaf, however, of *Phaseolus multiflorus* cut off at the pulvinus" and put in water may form roots and live for months and this is also true of *Ficus elastica* (8, p. 164). This power is possessed by the cotyledons of various plants even if cut into pieces (8, p. 164). So we have here a line of study to ascertain the cause of these well known differences in plants. The germination of the seeds of citrus plants and the Cucurbitaceae within the closed fruit is not rare and may perhaps be due to temperature conditions. Even when the seeds turn green this may be due to pathogenic conditions, or to a disturbed state of nutrition (1, Bd. I. p. 318). That some plants form active chlorophyll in darkness is well known. Cotyledons make but little or no food while filled with reserve materials even if green (9, p. 596). Although sometimes colored when exposed to light, roots generally are colorless. Nevertheless in Menyanthes a small amount of chlorophyll is produced (8, p. 166).

The importance of root-hairs merits further study. Schwartz (10) has shown that there may be as many as 230 root hairs per square millimeter and that these increase the absorbing surface as much as 12 times. The location and development of the root hairs give an excellent indication of the capabilities of the root for absorption. Various external conditions influence their development. According to Schwartz they are absent in *Allium cepa, Cicer arietinum, Cucurbito pepo, Helianthus annuus, Phaseolus multiflorus, P. communis, Ricinus communis* and *Zea mays* when the plants are grown in water. Some water plants do not produce root hairs except when they send their roots into soil (11, p. 194). Some root hairs may branch and remain unicellular (11, p. 25) as those of *Brassica napus.* There is the question whether new root hairs are ever produced between pre-existing ones or whether they always arise acropetally (11, p. 195). Snow (12) and others (13) have made valuable contributions to this topic.

Great interest attaches to the pegged and smooth rhizoids of Marchantia. If, according to one view, the pegged ones increase the absorbing surface and are of no mechanical assistance, we must also consider seriously the theory of Kamerling as to the service of the gas bubbles. At any rate this matter deserves thorough investigation (11, p. 202). The work on an individual root hair is small and it has been estimated that each hair will only absorb about .000,001 milligram (14, p. 242). However, their united action is great. Many problems

await solution concerning the trichomes other than root hairs found in plants.

In Tortula the rhizoidal cross walls are oblique (11, p. 204) when first formed. It is by no means decided that in this plant and in other mosses this oblique position is for the purpose of offering the greatest amount of surface for diosmosis and conduction in the filament. Some roots that normally grow beneath the ground when cultivated in clear water are in certain instances positively heliotropic and in others negatively so. This shows an ability to respond to a stimulus and is not inherited by them according to Darwinian principles (14, p. 733). Notwithstanding the admirable researches of Czapek on the corrosive effect of roots, the nature of the various secretions is still undetermined (15, p. 107).

Such questions as the following have a physiological bearing: juxtaposed or superimposed apical cells; the length of time a procambium cell can produce new elements; the physiological significance of anthocyanin; and quantitative estimation of transpirational reduction by felted trichomes (11). The irritant of *Urtica dioica* formerly thought to be formic acid but now determined to be an albuminoid substance (11) should be studied in other representatives of the genus. Other problems are iridescent plates of the Rhodophyceae, velamen condensation, and the significance of oblique palisade tissue (11); and the cultivation of various embryos as shown by Hannig (16) and others.

The old question of the ascent of water is still unanswered notwithstanding all that has been done to solve it. Strasburger studied the problem and arrived at certain valuable conclusions (1, Bd. I, p. 207) but was not able to explain the situation and, like the "noteworthy experiments" of Dixon and Joly (17), left the question undecided. The theory of Sachs soon became untenable although the force of imbibition is sufficient for the purpose. The great force of imbibition is shown by the swelling of starch which according to Rodewald requires a pressure of 2,523 atmospheres to prevent it (1, Bd. I, p. 63). In dried seeds imbibition and osmosis work together. This force is sometimes made use of to split skulls for anatomical purposes (1, Bd. I, p. 63). This force is, however, small in comparison with the freezing expansion of water at —20° C. which would require a pressure of 13,000 atmospheres to keep ice from forming (1, Bd. I, p. 29). Thus, we have the reason for the formation of frost rifts in the wood of various trees. These rifts are mostly radial and along the lines of least resistance (1, Bd. I, p. 307). The loud pistol-like reports often heard in living timber during extended and very cold weather indicate the formation of these rifts. The question of pressure affects even the plant when growing for it was first shown by Hales and afterwards by Kraus (1, Bd. I, p. 74) "that tree stems and fruits swell slightly at night and decrease in the day time due to transpiration although such changes in tree trunks are generally less than one per cent."

Other questions that crowd themselves on our attention are: the pressure necessary to close bordered pits; the physiological importance of tyloses; certain functions of leptome parenchyma, especially in relation

to the laticiferous system; the significance of the Casparian strips; and the meaning of guard cell fusion in Azolla and Funaria (11). Haberlandt was able to grow sporangia of Funaria in a culture solution for three weeks during which time normal spores were formed thus showing the efficiency of the chlorophyll system (11). The so-called secretion of wax by certain stomata requires further study (11). Uncertainty exists with reference to the secretions of certain glands as capitate and scutate ones (11) and elaioplasts (18). Objections have been offered to Tyndall's (11) interesting investigations concerning a layer of air saturated with ethereal oil which it is argued protects the parts concerned against heat, cold, or excessive transpiration. Do enzyme reservoirs contain protein material in addition to the enzyme (11)? Why are such large amounts of lime required for plants with cystolithic structures (11)?

There is the difficult problem of the dehiscence and cohesion mechanism of anthers, sporangia and other structures (11) which has occupied the attention of so many observers and has been so often the topic of research. Although these cases are of a physical nature, they are also of physiological interest and are still partly unsolved. The immense amount of work done on living motor tissues in the Urticaceae, *Stylidium adnatum*, and *Cyclanthera explodens* leave many points in doubt (11). It is moreover, remarkable that tactile pits have thus far been found in the walls of sensory cells only in the Curcurbitaceae and possibly also the Sapindaceae and tactile papillae only in floral organs and tendrils (11). The work on tactile organs of carnivorous plants, first recognized by Edwards in 1804, (11) leaves much to be done. In *Drosera rotundifolia*, Darwin found that a hair weighing .000822 milligram produced a noticeable reaction (1, Bd. II, p. 461) while, according to Kemmler, the least weight that will produce a stimulus on a sensitive skin is .002 milligram (1, Bd. II, p. 423). The causes of certain changes in the rate of growth of tendrils are unknown (1, Bd. II, p. 443). The epidermal lens cells of the epidermis as studied by Haberlandt present an interesting field worthy of further study. His photographs of a portion of a microscope made in connection with one of the membrane lenses show their capabilities (19).

The transmission of stimuli varies according to the kind of stimulus. Thus, Czapek (20) and others state that geotropic and heliotropic stimuli travel two millimeters in five minutes. Traumatic stimuli, according to Kretschmar (21) travel one to two centimeters per minute and Fitting (22) gives the rate as one to two centimeters per second for the tendrils of *Passiflora coerulea.* In *Mimuosa pudica* the velocity is about 1.5 centimeter per second (11). Questions as to the exact part played by the protoplasmic threads between the protoplasts are unanswered. Chemical stimuli in Drosera are transmitted only about ten millimeters per minute. Darwin found that .000423 milligram of ammonium phosphate would cause curvature of a tentacle (1, Bd. II, p. 463). The question remains as to what response if any is due to external causes. The origin of certain stimulatory movements is also

obscure. The quick movement of cilia after a stimulus shows its rapid propagation.

Physiologists differ as to the origin of excentric growth in roots and branches (11). The question of annual rings still awaits a solution (1, Bd. II, p. 274) along with certain ribbon shaped stems (11). On the subject of osmosis and plasmolysis, various questions remain for solution. How does a diatom retain its form in spite of the internal hydrostatic pressure (1, Bd. I, p. 122)? In the case of plants whose roots have been killed by heat the stems may remain living for several days but no experiments have as yet been made on their transpirational behavior. No exact work has been done to ascertain the influence of external agencies on the excretion of water pores. Similarly, doubt still surrounds the methods of sugar secretion by glandular cells and the means by which gland cells escape injury by high osmotic forces (1, Bd. I, p. 265) and other factors notwithstanding the large amount of excellent work that has been done on the subject.

The objections to the plasmolytic method are negatived in as much as verification of the method is easily obtained in various ways. Ostwald (23) has given an illustration of the membrane concerned and osmotic pressure in a theoretical way. The cryoscopic and other methods give results of great value. De Vries used the plasmolytic method to determine the molecular weight of raffinose and his results have since been confirmed (24). Moreover the work of Pfeffer has been confirmed again recently by Morse (25) and others who have made notable contributions to the subject. Among these the work of Fitting and Renner may be mentioned. Various questions arise concerning the conditions, under which natural plasmolysis occurs. Although a new cell wall may sometimes form around a plasmolysed cell which may remain living from a few hours to several weeks, nevertheless permanent plasmolysis produced and maintained artificially always finally causes death (1, Bd. II, p. 331). The specific difference in these cases deserves careful study. Taking the work of Pfeffer as a basis, Van Hoff founded his well known theory. Van Hoff also discovered the R. G. T. rule concerning chemical reactions and Kanitz showed its applicability for various cell activities (20). Recently much work has been done on osmotic pressure from a quantitative standpoint, on osmotic equilibrium, on permeability of organic membranes that are not protoplasmic in character, on the magnitudes of osmotic pressures and electrical conductivity and on osmotic pressure as it relates to distribution, morphology and growth (26).

With regard to the protoplasm numerous questions of direct physiological importance remain unsolved. For example, questions concerning cohesion and viscosity as well as the variation in surface tension need elucidation. Much interest also attaches to the various theories of protoplasmic streaming and much remains to be done concerning the effect of different chemical substances and other conditions (27). Temperature combinations with certain anaesthetics require attention. The locomotion of various diatoms and ciliated spores about which certain points are not clear is more rapid in proportion to their size than any

of our vessels that move on water. The recent valuable list of papers by Haberlandt on "The Physiology of Cell-Division" deserves consideration in this connection.

Overton (28) presented a rather plausible theory concerning the permeability of the protoplasmic membrane which was afterwards supposedly confirmed (29). Later studies, however, have thrown a cloud of uncertainty over his rather ingenious theory and further study of this important subject is necessary. The question of the penetration of aniline dyes into the living protoplasm was worked out by Pfeffer (30). The exact way in which an accumulation of dye occurs in certain plants remains to be explained.

Pfeffer's (30, Bd. I and II) work on chemotaxis is also of far-reaching importance. From the osmotactic standpoint the question arises concerning a tactic or phobic response in strong solutions. Spermatozoids and bacteria (1, Bd. II, p. 813) were caused to enter a capillary tube containing only .00000001 milligram of malic acid or peptone. Relatively, these amounts are not so small as they would seem since the sperms weigh only about .00000025 milligram and a cell of "*Bacterium termo*" about .000000002 milligram. On the other hand stronger solutions having an osmotic value of 0.5 per cent KNO_3 produce negative osmotaxis (1, Bd. II, p. 813). Englemann has introduced an excellent method of demonstrating chemotaxis in which certain organisms such as "*Bacterium termo,*" *Spirillum undula* and *Spirillum tenue* are used. By his delicate test .000000001 milligram of oxygen can be detected (1, Bd. I, p. 292).

In the various processes of growth interest attaches in many ways. The position of the nucleus in growing parts such as root hairs may not always be in the most active part of the cell as the writer has shown. The rapid growth of certain plants or plant parts is well known. It is estimated that "a bacterium can under favorable conditions divide in 20 to 30 minutes. At this rate in three days 4,772 trillions of individuals would be produced."

Can all plants live when continuously illuminated? Plants in the polar regions do this and McKinney has shown that a certain amount of continued illumination is without effect (31, p. 222).

Growth may be checked locally by cold and still continue at other points. This was well shown by introducing the top of a defoliated clematis plant into a hothouse. Leaves were formed on the stem in the greenhouse while the part outside was still frozen and dormant (32). This development of transpiring leaves proved that in spite of the low temperature outside a large amount of water was absorbed by the roots from the frozen soil and carried through the stem. Knight long ago demonstrated that a plant exposed to transitory cold sprouted earlier than those maintained continuously in a greenhouse. The same phenomenon was observed by Pfeffer in various plants and by Müller-Thurgau in potato tubers (1, Bd. II, p. 266). Molisch reports that potato tubers placed at once in an ice box for 14 days at +1 to 3°C will grow at once if planted in a warm house. In case of an early variety one may thus obtain two crops in the same year (33, p. 272). Plants

growing in northern regions, ripen as a rule in a shorter time and here the question of illumination or other causative factors requires further study.

Many deciduous plants continue to cast off leaves and form new ones even when removed from temperate zones to the tropics. Oaks and beeches never cease to do this, while others such as the cherry gradually become evergreen in Ceylon but cease to bear flowers. The peach, on the other hand, produces flowers and fruit during the entire year (1, Bd. II, p. 271). Experiments of this kind are much to be desired in temperate climates where artificial conditions could be supplied. It is difficult or impossible to cause many plants to bloom out of season while others lend themselves more or less to the process of forcing. However, artificial forcing causes abnormal development in some plants, as in the case of Lily of the Valley which is caused to develop the flowers before the leaves (7, p. 238).

A good many questions are concerned in the solution of certain points connected with periodicity. The experiments of Johannsen (34) show that treatment with ether or chloroform for 12 to 24 hours will cause the buds of such plants as *Syringa vulgaris* and *Prunus triloba* to open three to six weeks earlier than the plants not so treated and the activity of various functions was increased. Elfing and Lauren had observed before this that ether or chloroform increased respiration if the doses were not too strong, although this has been questioned. Molisch (35) has shown that if certain plants are immersed in water at 30° to 35° C, for 10 to 12 hours the resting period may be terminated. For example, a hazel branch one side of which was subjected to warm water bloomed in nine days while the other side which was untreated was still in the resting condition. *Forsythia suspensa* bloomed in 12 days after such treatment while the control was still unopen. Syringa bloomed 40 days after the warm bath while the control was still dormant. The responses shown in these experiments leaves certain questions unanswered.

Fitting's experiments (36) with *Erodium gruinum* and *E. ciconium* are interesting in this connection. He found that when, on a cool morning, deep blue flowers of these species were put in a box having a temperature of 40° to 42° there occurred quickly a sudden change of color. Within three seconds the blue flowers changed to a light rose and a few minutes later to a bright red. When returned to a cool place the blue color soon returned. Furthermore, the reaction of the cell sap is often indicated by the color of various living cells. Thus, the red color of rose petals and beet-roots shows that the cell sap is acid while the blue color of the hyacinth, blue bell, or cranberry shows that the sap is neutral or slightly alkaline (1, Bd. I, p. 490). We also have striking color changes caused by oxidases. Among these is the brown color assumed by the exposed flesh of apples, the prussian blue shown by Boletus when broken and the dark color of raw rubber (37, p. 390). The oxidation of the sap of Rhus to a black lacquer varnish in air by laccase is also well known.

Other properties of the enzymes are noteworthy. The dried sub-

stance of diastase, protease and ereptase of wheat and barley may retain its activity for 20 years and after the power of germination is lost (37, p. 390). Finely divided platinum and iridium among inorganic substances cause a catalytic action resembling that of enzymes. Buchner's discovery that the filtered sap of yeast plants can change sugar to alcohol and carbon dioxide, is interesting in this connection. The capability of diastase to hydrolize 10,000 times its volume of starch and invert 100,000 times its volume of sugar shows its great power. The yeast plant itself is active in various ways; thus it can reproduce 20 or 30 times in the absence of oxygen, it can produce alcohol up to 14 per cent before the yeast plant is killed, and it may produce a pressure of 25 atmospheres of carbon dioxide in a closed vessel before such action ceases (1, Bd. I, p. 576). Nägeli (38) estimates that the volume of a cell of beer yeast is about .000002 cubic centimeter and weighs about .0000005 milligram. The great numbers, however, make up for their diminutive size.

Bacteria also show activity in some of these directions. A closed flask, for example, containing a nutrient solution colored with indigo carmine and inoculated with certain bacteria will lose the blue color due to the removal of every trace of oxygen by the bacteria. On readmitting oxygen the blue color will return. In proportion to their bulk some bacteria may use oxygen 200 times as fast as man (1, Bd. I, p. 526). Certain bacteria will live in carbon dioxide under 50 atmospheres of pressure and may burst tin cans of conserves by developing such gas pressures. Small amounts of carbon dioxide thus given off may be estimated conveniently by a method given by Hempel (39) and extremely small amounts of carbon dioxide can be detected by the biometric method for seeds and other objects as devised by Tashiro (40).

The subject of phosphorescence presents an interesting field for investigation. For the already voluminous literature, one is cited to the recent work of Czapek (41), Molisch (42), and other contributors. Whether one holds to the extracellular, intracellular, or other theory regarding the production of light in different plant forms, various questions arise. The sudden increase or decrease in the strength of the light emitted requires explanation, as does the effect of different pressures of oxygen and the actual oxygen consumption by the organism in its formation of light. The light intensity may be sufficient to produce clear photographs of various objects, to produce heliotropic curvatures, and to read by, especially when "bacterial lamps" (42) are used, and is equivalent to about .000785 of a Hefner unit per square meter. The meaning of the necessity of a large amount of sodium for luminous bacteria is important as is also non-motility and light production in certain forms (31, p. 213).

Many interesting points regarding diffusion await solution. The diffusion of gases ordinarily takes place comparatively slowly as shown by Clausius (43, Bd. 3, p. 753) in connection with whose work the theory of diffusion by Maxwell was founded. Ewart (44) has shown that in certain cases diffusion causes the distribution of substances more rapidly than streaming. Osmotic pressure varies only slightly

(45) in plant cells within the temperature range ordinarily present, for a rise of only 15° C. causes a pressure change from 100 to 105.5 (1, Bd. I, p. 120) and this, to a degree, follows the laws of gaseous pressure (46). Brown and Escombe have opened up an interesting field in showing that the diffusion of CO_2 is not dependent on the size of the leaf pores but is proportional to their diameter (47). In like manner the diffusion of CO_2 as first shown by Graham constitutes an interesting topic. A study of diffusion in gelatine as investigated by Hüfner and Hagenbach (43, Bd. I. p. 445) and compared to protoplasm would be of value. Further studies are needed concerning the behavior of certain cell walls to the diffusion of liquids and gases. Conduction of food materials takes place rapidly in some parts, but is prevented entirely by girdling. The length of life, however, of that part of a tree above the girdle varies.

Many problems remain concerning the storage of food. Trees for example, are distinguished from annuals because the latter store their reserves permanently only in the seeds, and they differ from perennials because the latter store their reserves subterraneanly (48, p. 225). Many problems arise concerning the nitrogen question, particularly regarding autotrophic plants. There is the question of nitrites and nitrates and especially a question of nitrites in developing green plants. Questions arise concerning vegetable proteids and their synthesis, under certain conditions and points relating to sulphur. Plants of *Chenopodium vulvaria* and flowers of *Crataegus oxyacantha* evolve a nitrogenous compound in such quantity that a glass rod dipped in hydrochloric acid emits fumes when brought under a bell jar with such specimens. Wicke says this substance is trimethylamine in Chenopodium (49). The nitrogen problem is one requiring investigation by both physiologist and chemist.

Ethereal oils constitute a question. In *Dictamnus albus* the oil may vaporize to such an extent as to ignite when a flame is brought near it and hence many such flowers may be more fragrant at night (1, Bd. I, p. 502). In the daytime, however, the change in the diathermanicity of the air which would assist in reducing the heat of the sun's rays would be slight notwithstanding the efficiency of these vapors in that respect as mentioned above (50 and I, Bd. II, p. 848). Green and other colored leaves can absorb 50 to 90 per cent of the sun's energy (50). Certain species of Citrus possess highly inflammable oil. Among cryptogams the oily nature of certain parts is well known. In Lycopodium the spores flash into a beautiful array of scintillations on ignition, hence their frequent use in pyrotechnical displays.

Oligodynamic studies will bear further inquiry. Grafe has made valuable studies on cell chemistry and Haas and Hill have recently mentioned various metabolic problems (51). Electro-culture and the physiology of seedlings are worth-while problems. In 1878 Sachs stated that an electric current passed from the stigma to the ovary pedicel of Berberis stimulated all the stamens, but when sent in the reverse direction no stimulation was produced (14, p. 685). Other stimuli produce comparable results, for when plants are passed from dark to light and vice versa the stimulation is different (1, Bd. II, p. 504).

A stimulus may be positive at one intensity and negative at another. Geotropism is positive for most roots although moisture conditions may reverse this reaction. Most stems are positively heliotropic but in Linaria this undergoes a natural reversal since the young flower stems are positively heliotropic, becoming negative as they elongate (52, p. 318). Agapanthus and Papaver are similar examples.

Questions of symbiosis and metabiosis also arise. Just as numerous questions presented themselves concerning photosynthesis, we also have the field of chemosynthesis with many unsolved problems. Sugar may constitute a product both in constructive and in destructive metabolism and hence a physiological and chemical classification will not agree (48, p. 262). Questions have arisen concerning the wave length of light best for green plants. Pfeffer gives it as between Frauenhofer's lines C and D of the spectrum and of 660-680 uu wave length (1, Bd. I, p. 330). Reinke's (53) spectrophore can displace diffraction grating in certain experiments of this kind. The growing of lichens on windows of houses and their mechanical action shows unusual capabilities (54).

The prevention of flower wilting by the use of $PbNO_3$ deserves further study (55). The change of color of flowers due to a change of temperature, as above referred to, has a partial parallel in the enantiotropic substance, mercury iodide, and a further striking parallel in the double salt $Cu_2\ I_2\ 2HgI$ which changes color from red to brown and to red again on cooling (56). Though not analogous the sudden darkening of the pulvinus of Mimosa after stimulation shows that water has taken the place formerly occupied by air (57). A continued study of Schumann, Roentgen and other rays as well as different colored lights in various combinations of temperature and gases would net further valuable results.

Certain problems concerning the chemical action of different plants need further attention as that of wood destroying fungi; the penetration of structures by bacteria as egg-shells (58); the reported corrosion of stone, mollusk shells, oyster shells, and oolitic iron by algae (41, 1920, Bd. II, p. 360); and the penetration of membranes by fungal filaments (59). The unusual reported case of algae growing on a painting for about 200 years shows the capabilities in certain directions (60). Of the halogen group iodine and bromine are found in marine plants, as would be expected and probably in land plants (1, Bd. I, p. 433) though the latter is contradicted by Fresenius (61, p. 542). Other questions arise on this point. Lead is often present in plants but a practical method for its volumetric estimation is lacking according to Fresenius (62) and Sutton (63) advises weighing for its accurate determination. The chemist can assist in the many plant problems by determining substances in plants, but he cannot tell what ones and the amounts necessary for the proper functioning of the metabolic processes. This the plant physiologist must determine by actual experiment.

Facts in physiology once established are often disbelieved or forgotten. For example, the neglected work of Ingenhousz on the obtaining of carbon by green plants was afterwards brought to light by Liebig; the water-culture method first used by Woodward was subsequently

resuscitated by Sachs (1, Bd. I, p. 412). Many such examples in physiology could be mentioned. The forgotten work of Mendal was resuscitated by de Vries, Correns and Tschermak almost simultaneously (48, p. 504) and also the restoration of the now famous work of Conrad Sprengel by C. Darwin.

Then there is the physical question of the Brownian movement, long known and of interest to all scientists. The chemist also looks for forms of energy in the atom by a rearrangement of the protons and electrons and the energy of radioactive substances (64). The determination of Hydrogen Ions much referred to, especially of late, presents many questions which the botanist would do well to work in conjunction with the chemist. The sensitiveness of the bacteria method, above referred to, exceeds that of various chemical methods ordinarily employed (65) and hence its extreme usefulness to the physiologist.

The chemistry of plant odors presents many problems. Many plants, such as *Ageratum mexicanum*, have no special odor during life but when killed by drying, freezing, or heating to 60° C., they give off a very pleasant odor of cumarin (33, p. 274). Similar odors appear in *Asperula odorata*, *Anthoxanthum odoratum*, *Prunus cerasus* and vanilla plants and the well known instances of hay and other plant odors. We can smell .000002 milligram of oil of roses and .000000002 milligram of mercaptan (66, p. 97). The topic of transpiration presents many problems. Hales (67) proved that the flow of water may be reversed in a stem and Strasburger verified this by cutting off a tree trunk near the base and which was naturally grafted about one meter above the cut. The cut-off stem remained fresh for years (68). A summarization of transpiration and the literature is given by Burgerstein (69) up to 1920.

There remain questions about carbohydrates and fats. In some plants no starch is formed in the chloroplast (52, p. 223) and in others cane sugar formation precedes that of starch. Questions arise concerning the absence of some polysaccharides in certain plants and some doubt still exists on the functions of mono-di- and poly-saccharides (1, Bd. I, p. 468).

Carbon is necessary for the metabolism of plants and as Noll says, no other element can enter into the formation of so many and such a diversity of substances in the organism or in the chemical laboratory (70). A reference to the works of Richter and Beilstein will substantiate this fact. According to Chamberlain (71) the number of carbon compounds now exceeds 200,000.

The well known process of abscission or leaf-fall can be brought about in various ways. Further research is needed to determine whether the production of organic acids is actually operative at the end of the summer according to Wiesner's view or if organic acids may have any influence (1, Bd. II, p. 278). In this connection it is interesting to recall the work of E. Hannig on the casting off of flowers as a result of external conditions and the field for investigation brought to light by his experiments. Several points concerning the action of poison by increasing the temperature as well as the differences in the resistance

of plants to heat require study. Pouchet found that the seeds of Medicago would germinate after boiling in water for four hours (1, Bd. II, p. 294) while the seeds, from stone fruits that have been made into jam, germinated (9, Vol. II, p. 230). The subject of desiccation leaves numerous questions to be settled. Much attention has been given to a study of the effect of freezing on plants but still it is not known why freezing kills some plants and does not affect others. The resistance of bacteria to freezing requires further explanation (1, Bd. II, p. 314). The resistance of trees which form oil in cold weather as well as the ability of the same plants to withstand cold at different stages of their development needs solution (1, Bd. II, p. 317). A single reference to the work of Müller-Thurgau, Molisch, Göppert, Winkler and Kylin must suffice here. This topic forms a subject of great interest and its value can hardly be over-estimated. Even in reasonably cool situations plants may sometimes be injured by drops of water which concentrate the sun's rays. The resistance of certain marine algae which grow at -1.8° C. requires attention, as does the statement that the spores and mycelia of Mucor are equally resistant, and whether or not ice forms in turgid bacterium cells (1, Bd. II, p. 310).

Dry spores such as those of Aspergillus and yeast are only slightly or not at all injured by submergence in absolute alcohol, ether, benzol or carbon dioxide. The point now arises how they would compare with spores in air (1, Bd. II, p. 324). Do roots of seedlings require gradual moistening to recover and live after drying (1, Bd. II, p. 324)? A further comparative study of the spores of bacteria and seeds would net additional worthy results. Notwithstanding what has been done on the effect of different alkaloids and on the various poisonous plant substances, there remain many problems for investigation by the physiologist.

Certain questions concerning the germination of seeds and the subsequent transfer of materials require investigation. There are questions of cortical and medullar functions which need attention. Schimper (72) has shown that the bundle sheaths in Plantago could convey substances, but less rapidly, after the removal of the fibro vascular bundles. In young tissues the Biuret reaction is useful in showing the disappearance of certain substances, as soluble proteids. Companion cells need study and the questions concerning latex are by no means settled. The writer by depriving the seedlings of Papaver of their latex checked the growth but did not kill the seedlings. The same experiment the author has performed on certain sieve tubes with similar results. Schwendener states that no latex escapes from withered plants or old parts when cut (1, Bd. I, p. 594).

If nine tenths of all phanerogamic seeds possess oil, as Nägeli states, it can be seen that this does not necessarily protect them from desiccation. (1, Bd. I, p. 609.) Puriewitsch and others planted grains of certain plants from which the embryo had been removed and the endosperm was neither changed to sugar nor removed. When, however, the place of the embryo was taken by substituting a small cylinder of gypsum whose lower end reached into water, to remove the forming

sugar, the starch was completely removed from grains of maize or other plants (73).

In the field of microchemistry much of interest to the plant physiologist remains to be done. This work has been ably carried out, especially by Tunmann (74) and Molisch (75). The application of chemistry should go hand in hand with plant physiology. As we glance through the latter subject we see, as a rule, far too little of the use and knowledge of chemistry. The masterful work of Czapek (41) and others have rendered service of great value along this line. With this brief idea of physiology's great helper we turn our attention in conclusion to some special problems where it is concerned.

A change took place in chemistry when Wöhler in 1828 obtained urea from ammonium cyanate and thus produced for the first time an organic from an inorganic compound. Then Kolbe synthesized trichloracetic acid in 1845 and Berthelot synthesized alcohol from formic acid thus removing the boundary between organic and inorganic chemistry (76). Organic chemistry, the chemistry of carbon compounds, has tried to do what plants do, and in many cases has apparently succeeded. The plant no longer furnishes alizarin and indigotin for commerce which are now obtained from coal tar and even some alkaloids have been prepared artificially.

Since colloids were first investigated by Graham the similar nature of protoplasm has given their study a significance. Later the principle of Tyndall's phenomenon was applied by Zsigmondy to the so-called ultramicroscope so that protoplasm and living cells can be studied to advantage. Recently Czapek (77) has investigated the question of surface tension in plant cells and has called attention to the application of Richardson's Law. We have to do here especially with the behavior of two important substances in the plant cell, protoplasm and chlorophyll. Their activities go hand in hand in green plants. We shall now turn our attention to the behavior of the chlorophyll in particular. Glancing backward we recall that the green coloring substance of plants was recognized by Nehemiah Grew (78) in 1682 and that it was given the name of chlorophyll in 1817 by Pelletier and Caventon (41, Bd. I, p. 556). Numerous and valuable contributions have been produced in rapid succession and yet almost 250 years after Grew's work the performances of this riddle are unsolved. Colored lights have an effect on certain plants, for it is claimed that in red light specimens of Oscillatoria become green, in green light they turn red and in blue light assume a yellow hue (79, p. 245). Problems in great number remain to be answered as questions concerning a chloroplast membrane and the influence of chloroplasts on various cytoplasmic movements (79, p. 251). The positions assumed by chloroplasts so ably investigated by Stahl and Senn (80) still leave many points to be solved. The question of structure in certain respects is still doubtful as is the exact form of the chlorophyll in the chloroplast and points concerning yellow pigments (1, Bd. I, p. 297).

The greatest advances on the subject of chlorophyll so far are the investigations of Willstätter and Stoll (81). Their published papers deal

with the chemical side of the question and are of such great importance that they are indispensable to an understanding of the subject. But the function of chloroplasts interests us most. Among the questions are thé formation of starch and other substances; the first-formed products; is the same course always followed in sugar production; and the chemistry of pigments. Can oil produce starch or vice versa in the chloroplast independently of the cytoplasm? Are glucosides direct products of photosynthesis? Further studies should be made on the retarding influence of higher carbon dioxide percentages and on the more or less complete loss of photosynthetic power by normal chloroplasts. Is the protoplasm of heliophobic plants more sensitive to light than the chloroplast? (1, Bd. I, p. 285.)

The evolution of oxygen from water plants directed the attention of Ingenhousz to the photosynthetic processes in green plants and his work in connection with that of Senebier and De Saussure constitutes one of the most important scientific discoveries. Iron is necessary to chlorophyll formation, but the action of iron and alum in causing the reddish flowers of Hydrangia to become blue is uncertain (1, Bd. I, p. 421). Chemical reactions often occur with great velocity. So we may have an immediate cessation or recommencement of oxygen evolution in green plants as shown by the extremely sensitive bacteria method. In light, starch (1, Bd. I, p. 303) is produced in five minutes in considerable amount in Spirogyra which previously was starchless (82). Detmer has shown that the iodine reaction of starch can not be obtained in distilled water (83). No means of stabilizing this reaction is known. We have a great many chemical changes occurring in tiny green cells whose total volume often does not equal 0.1 cubic millimeter. Since the air contains only .03 to .04 per cent of carbon dioxide the work necessary on the part of the green plant to make its food will be easily understood.

Light we know is necessary for chlorophyll action, therefore it is not surprising that moonlight which is about 1/600000 the strength of sunlight would prevent the handling of CO_2 and even with light of 0.1 to 0.025 the strength of sunlight respiration and photosynthesis about balance (1, Bd. I, p. 323). Plants in dwellings often suffer from deficient light since at 0.5 meter from a window the plant gets only 0.3 and at a distance of two meters only 0.08 of the light it would get in the open sunlight (1, Bd. I, p. 323). When the sunlight falls on a thin green leaf most of the energy is usually absorbed so that the light which passes through would not cause the formation of starch nor an evolution of gas (1, Bd. I, p. 329). Copper beeches due to their color and light interference grow more slowly than vividly green species, other conditions being equal (84). An oleander leaf will produce per square meter in sunlight about 0.000535 gram of starch in one second, obtaining thereby energy equivalent to 2.2 caloric units, which is less than one per cent of the energy of the sunlight (84). Under good conditions other plants such as the pumpkin may produce in 15 hours 25 grams of starch per square meter (85) which necessitates the removal of the carbon dioxide from 50 cubic meters of air. The quantitative

activity of the green plant is therefore easily realized. Recently studies have been made concerning carbohydrate substances of Thallophytes, Bryophytes and leaves of Angiosperms and methods for their estimation in the extracts (86). The amount of chlorophyll is really very small per unit area and Tschirch has estimated that only 0.1 to 0.2 gram is usually present per square meter of green leaf surface. Much work remains to be done on chlorophyll activities with various autotrophic plants of different colors and under different conditions of light composition. Marine plants suffer from light conditions as the water deepens and at a depth of 400 meters in the sea autotrophic plants cease to exist (1, Bd. I, p. 337). The chloroplasts of some plants can continue to live and carry on the process of photosynthesis for a short time when removed from the cell (87), but all attempts to grow them outside of the cell permanently have failed. The chlorophyll of green plants breaks down in solution. Wahmsley (88) states that he has preserved a specimen of Draparnaldia in camphor water for 20 years and that the chlorophyll remains unchanged. This, however, says nothing as to the actual preservation of the chlorophyll itself. Concerning those substances which form the chlorophyll only a faint intimation exists which creates a wide field for study.

A large field for investigation is brought out by Fitting in his interesting paper on a new branch of physiology which he names "Geographical Physiology" (89). The various theories concerning carbon dioxide assimilation have been well summarized by Schroeder (90). One which is much quoted may be mentioned, namely Bayer's Theory "according to which formic aldehyde is produced from carbon dioxide and water in the chloroplast, oxygen being evolved, and carbohydrates resulting by polymerization" (1, Bd. I, p. 340). Doubt attaches to this theory. More recently Ewart states "that not formaldehyde but a biose sugar is the first product in photosynthesis and the traces of formaldehyde which have been detected in green plants are the result of the destructive photo-oxidation of chlorophyll and are formed equally well in the entire absence of carbon dioxide when extracted chlorophyll is exposed to light" (91). Attention is also directed to the question of photosynthesis and the Electronic Theory (92).

Professor Giacomo Ciamician of Bologna, Italy, made an interesting address some years ago in New York which has a bearing in this connection. He asked "why use only the fossil energy of the sun—for that is what we do when we burn coal! Why should not man use sun power, direct, as do plants and trees?" (93) According to one estimate he made, the sun delivers in energy by means of its rays enough power in six hours to equal 2,500 tons of coal per square mile. We mine in the U. S. about 600,000,000 tons of coal per year while the Sahara Desert receives daily in solar energy the equivalent of 6,000,000,000 tons of coal every day. He indicated by a long list of chemical processes the probability of the consummation of his ideas and prophesied a trend toward the tropics which would on this account become thickly populated in time. Slosson says "man takes a 1,000 horse power engine and an electric furnace at a temperature of several thousand degrees to get

carbon into combination with hydrogen, yet the little green leaf in the sunshine does it quietly and without getting hot" (66, p. 239).

One of the tasks of the future is to ascertain, therefore, if possible, the various ways by means of which green plants make their food substances and to follow out the chain of processes completely. Green plants get their energy from the sunlight and build up their structure. They have done this in past ages, and of this we have an expression in coal deposits, which are of proved vegetable origin (94). A knowledge of these various plant processes is all the more important since our timber supply is virtually gone. When we burn wood we release the energy of the sunlight which was stored up in the plant by the process of photosynthesis. By this transformation of potential into kinetic energy the activities of the green plant are reversed. And when we burn coal, formed as above indicated by green plants, which collected the sun's rays of many thousands of years ago and stored them, we release this energy in the form of heat by the process of combustion. And so with our forests, nearing exhaustion as a fuel resource and the end of our available coal in sight we realize that some other source of energy must ultimately be obtained. The recent coal strike furnished sufficient evidence to convince the railroads and other industries that coal was necessary to keep them in operation. Possibly a successful study of the various chemical and other processes of the chloroplast will later assist in throwing some light on this very important subject. With these suggestions and indicated problems some of which are old, many recent, and others in progress, some idea may be gained of the numerous opportunities for study which the subject of plant physiology offers.

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FRANCIS GALTON, LIFE AND WORK.

ROBERT HESSLER, Indianapolis.

Francis Galton was born one hundred years ago near Birmingham, England. Early in life he took up work in neglected fields. He became a great man of science and developed Eugenics, a system or science concerned with improving races by breeding.

He was a contemporary of Charles Darwin (his cousin), of Thomas H. Huxley, Herbert Spencer, and of a number of other noted men—men whose insight and aid were valuable to him in developing his own ideas and his work.

More specifically, Galton was born under a most favorable and healthful environment, amidst green fields, with long-lived ancestors, intellectual and well-to-do parents, with four sisters and two brothers older than himself. A sister made it her duty to look after his early education. Formal education in school and college he bore badly, for there is repeated mention of ill-health. He instinctively sought the open-air life, which to him spelled health. He was able to bear great physical exertion and exposure, a trait of value to him in exploring expeditions and which he believed he inherited from his mother's side—just as he looked upon his tendency to bronchitis and asthma as an inheritance from his father's side. Euthenically considered, it appears, however, that he overlooked the fact that his great-grandfather was country-bred and reacted on removing to the city, just as his father reacted, and as he himself reacted; for he had stated that he could not bear close, warm, and carpeted rooms.

On his mother's side both his grandfather and great-grandfather had been physicians and his mother desired him to follow in their footsteps. This he was willing to do and he entered hospital work, but during his university studies his health failed. About the time he completed his medical education his father died, and being left with independent means he never became a practitioner. The family now broke up, and he himself took to traveling and became a noted explorer.

In his *Memories of My Life* he mentions getting married and the value of marrying into a good family, but there is no mention of any offspring. References indicate that he had much ill-health in London, and he became a bird of passage, leaving the city on the approach of the closed-door season for an open-air climate. His cousin, Charles Darwin, reacted even more acutely to city conditions and left the city entirely.

A centenary presents an opportunity to review a man's life and work, but unless an essayist is unusually well qualified he may hesitate to express any opinions—but he can at least voice his appreciation and admire the industry revealed by a long list of titles. A full bibliography appears in his autobiographic *Memories of My Life*, and reveals his various and successive activities. His chief works may be referred to briefly:

The *Narrative of an Explorer in Tropical Africa* (1853) brought him the gold medal of the Royal Geographical Society. Several papers

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and monographs relating to travels and geography followed. The *Art of Travel or Shifts and Contrivances in Wild Countries* appeared in 1855 and went through a number of revised editions. His attention was then turned to meteorology and he charted data on a large scale. From him we have the term anticyclone. He developed great proficiency in making charts, diagrams and graphs; by applying this knowledge to the study of anthropology he advanced it through statistical methods. He became interested in the subject of heredity, and in 1869 published *Hereditary Genius*—and formulated his ancestral law, that the two parents contribute one-half, the four grandparents together one-fourth, and so on.

A difficult problem is presented by the comparative worth or desirable qualifications of individuals and races. Galton believed that much could be accomplished through proper nurture. *English Men of Science, their Nature and Nurture*, appeared in 1874. At intervals and between larger works he employed himself with all sorts of seeming oddities, including the making of "Composite Portraits", on which he published in 1878. Then came his *Human Faculties*, for which he had collected a great mass of data. In this work he for the first time used his newly-coined term Eugenics.

Galton was a pioneer in neglected fields. He brought together a lot of material and from a careful study arrived at certain conclusions. Others have taken up his work and advanced it and presented it more systematically, but the name of Galton will always be associated with Eugenics.

A study of the lives and the books of the master minds enlarges our vision. Too many of us are controlled by our emotions—we may see only the need for immediate relief from misery and affliction. Few of us consider future generations nor the constant crop that calls for more and more relief. Great minds, as Galton's, are concerned with fundamental causes and with the diffusion of knowledge and prevention.

The measurement of physical and mental qualities was definitely taken up by Galton through the establishment of an anthropological laboratory. Today we hear much about psychological testing, a subject that was wholly new in 1884. The late war gave a great impetus to measurements, and at present school children, mainly in city schools, are tested from all angles—new and improved tests are constantly introduced. In *Natural Inheritance* he again advocated the breeding of desirable qualities and the checking of the undesirable. His observations on Finger Prints appeared in 1893; the practical value of this was soon recognized and developed.

In 1904 Galton founded a research fellowship at the London University for work in Eugenics, which has been a great stimulus to the whole world. In this connection attention may be called to the Galton Lecture of 1919 by Dean Inge of St. Paul's, which appears in his *Outspoken Essays*. This lecture is remarkable when we consider that it is by a noted churchman.

In England where life conditions for a long time have been fixed, static—"as the father so the son"—inheritance plays a great rôle; all in marked contrast to conditions in our own country. England, and the

old world generally, where there is no immigration problem, offers the best opportunities for the study of Eugenics. Our own country is in a constant flux, dynamic; there is no predicting the vocation or career of the son of even the humblest citizen. Uneducated parents may have ideals, and by giving the son a higher education may enable him to become a superior man. At present we do not realize how much talent is submerged, needing only suitable life conditions—a proper environment—to rise to the surface.

Galton's *Memories of My Life,* published in 1909, two years before his death, is a book well worth reading. From this autobiography we may again learn, that which stands out strongly in all his work,—that great minds are concerned with fundamental causes.

LIFE AND MIND.

ROBERT W. MCBRIDE, Indianapolis.

We live, and we think. What is life? What is that we call mind, of which thought is a product?

Science gives us no satisfactory answer to either query. The best it can do is to surmise, to speculate, and imagine; or, in other words, to guess; and some of the guesses seem to me extremely wide of the mark. While I am not learned in any department of science, I look with interest on the efforts of the real students of science to solve the riddle of the universe. But when the scientist reaches a point where he can only surmise, speculate, and imagine, I feel justified in making my own guess.

Modern science has opened for us wonderful vistas in every direction. It reaches out into space and tells us with certainty of suns so far away that light can only bridge the distance in more than a hundred thousand years. What this means can be appreciated, when we remember that light in eight minutes leaps across the ninety-three millions of miles that separate us from the sun. With equal certainty science delves into the depths of the infinitesimally small, until its discoveries stagger even imagination. It has made the earth's strata an open book, in which we read the story of the ages. It has harnessed the powers of earth and air and made them our servants. Wherever science leads us we find an apparently homogeneous universe, homogeneous in the sense that matter in the distant sun, as revealed by the spectroscope, does not differ from matter as we know it on this insignificant atom—our world, all apparently obeying uniform, unchanging, and unvarying laws that rule everywhere and everything, from the mighty sun as it wheels in distant space, to the tiniest animalcule revealed by the microscope. Such laws tell us unmistakably of an intelligence beyond our possible comprehension. While finite mind can only imagine infinity, we find in these things what seems to us infinity in space, infinity in duration, and infinity in that Power which lies back of and apparently originates that controlling law. That law is therefore the product of "Infinite Mind."

But with all its accomplishments, has science as yet succeeded in explaining any fundamental reality? Thus, the universe is composed of what we call matter. Science, explaining matter, long ago told us, with an air of absolute certainty, of ultimate atoms, the most minute particle into which matter could be divided, of molecules, and of many elementary substances. It now tells us that the atom is not the ultimate thing they once thought it, but that back of the atom lies the electron. It tells us that instead of the many elementary substances of which we were once assured, it is possible or it may be probable that there is only one single elementary substance, and that the so-called many elementary substances are simply due to the manner in which the electrons are arranged or grouped. The reasoning impresses us, but it comes to us with the frank admission that no one ever saw an electron.

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While time may prove that this theory is correct, I think it safe to say that the problem is not yet solved.

Again, I am bewildered when I am told about a conjectural, universal ether, that is supposed to fill all space, to be everywhere present—a something more dense than any known substance, and yet a something in which we freely move and in which the myriads of suns and planets revolve. Another one of science's guesses.

We ask science about that mysterious power that caused the falling apple to hit Newton's head and sent him conjecturing until he identified it with that power which rules the march of the worlds, and which we call gravitation. But when we ask what gravitation is, science answering only gives it a name and tells us something of the ways in which it acts. It cannot tell us what it is.

Among the many unsolved mysteries, is that of life. And here, again, science fails us. An article in the last edition of the Encyclopedia Britannica, which purports to tell us what life is, begins with the statement that life is

> "The popular name for the activity peculiar to protoplasm",

and follows with an inconclusive two pages that get nowhere, and does not even attempt any clearer definition or explanation.

The Encyclopedia Americana frankly says:

> "No definition of life has ever proved quite satisfactory."

It then quotes several definitions, including Herbert Spencer's amended conception of life, which I quote. It is, Spencer says,—

> "The definite combination of heterogeneous changes both simultaneous and successive in correspondences with external co-existence and sequences."

I quote this because of its lucidity and clarity. Quite as much so as a London fog.

None of these attempted definitions throws any light on what life really is. The writer of that article, after quoting several, says:

> "The most recent attempts have been in the direction of proving that life is merely a form of energy or motion."

This, I can begin to understand. True, Sir Oliver Lodge, who is universally recognized as one of the most eminent and learned of living scientists, tells us that life cannot be a form of energy. I quote from one of his latest published utterances. He says:

> "Life must be considered *sui generis*. It is not a form of energy, nor can it be expressed in terms of something else. Electricity is in the same predicament. It too cannot be explained in terms of something else. This is true of all fundamental forms of being. * * * To show that the living principle in a seed is not one of the forms of energy, it is sufficient to remember that the seed can give rise to innumerable descendants through countless generations without limit. There is nothing like a constant quantity of something to be shared as there is in all examples of energy.

> There is no conservation about it. The seed embodies a stimulating and organizing principle which appears to well from a limitless source."

He adds:

> "But although life is not energy any more than it is matter, yet it directs energy and thereby controls arrangements of matter."

Lodge here uses the term "energy" in the limited sense familiar to the physicist and defined by them as the power or capacity to work. Thus limited, he says life is not energy. This will also exclude gravitation and electricity from the list of modes of energy, for he admits that neither of them can be shown to conform to the laws governing the conservation of energy. I am a layman, and do not recognize this limitation as legitimate. To the layman, the word "energy" is one of the synonyms of the word "force." The Standard Dictionary defines the word "energy", among other things, as

> "The power by which anything acts effectively."

One of its definitions of the word "force" is, that it is

> "Any operating or operative *energy*; any active agency or power tending to change the state of matter."

Accepting these definitions as correct, it seems to me that gravitation, electricity, and life, are each and all forms of energy. It seems to me that gravitation, that power that holds the universe in its grasp, and electricity, as it lights our streets and homes and supplants steam in driving mighty engines, are certainly exhibiting forms or modes of energy.

To me, life is a force, one of the modes in which force manifests, for I believe that science is on the way to the demonstration of the unity of the so-called forces, as it has already practically demonstrated the unity of matter. That is, that as all the various so-called elementary substances are resolvable into one primeval form of matter, so all the various so-called forces are only various ways or modes in which one single force manifests itself. Life is the building or constructing and conserving force in nature. Sir Oliver Lodge says "it directs energy and thereby controls arrangements of matter." To me, instead of *directing* matter, it *uses* matter to build organic structures under the direction of that Infinite Intelligence which lies back of the laws which govern the universe. Instead of life directing matter, it is itself directed and the evidence shows that it slavishly follows the directions given it. To say that life directs, is to attribute to it intelligence. I can conceive of nothing in the action of life that indicates the possession by it of independent intelligence. The definition of life in the Encyclopedia Britannica, that "life is the popular name for the activity of protoplasm," seems to me flippant and unworthy of that great publication. True, protoplasm is the physical basis of life, that is, it is the vehicle or instrument by which and through which life's work is done. Protoplasm is not life nor is life protoplasm. Protoplasm, like other substances, may and does die, and dead protoplasm, like any other dead

substance, will decay or dissolve into the various substances which enter into its composition. Life is that which animates all things, from the animalcule or the bacterium to man, and it does its work by the exercise of force. Life drives that wonderful organ, the heart. It selects from the food the substances it needs, puts them in place, and casts off the residue. It drives the sap through the tree or plant, and unfolds the leaf or flower. Until stayed by death it is acting, and its action is force. The life which builds the tree, or paints the flower, does not differ from that which builds the man. Life is not an originator or a planner. It builds the various structures of organic life, but in so doing it simply follows the plans that are given it. The germs with which it begins its work in building a structure, are its trestleboards on which it finds the plans of that which it is to build. No microscope or other instrument devised by man can examine one of those germs and tell what it enfolds. That mysterious Intelligence that lies back of the great law is the architect that draws the plans, and life as it takes up its work with a given germ follows that plan without deviation, except as it may be interfered with by outside influences. An ovum and a spermatozoan encounter each other, they combine, and the stage is set and the actors are present for the drama of life. Life only waits for the proper and necessary conditions in the environment for the play to begin. Science may exert all its powers, but it cannot discover from that tiny germ what the production will be, but given proper conditions life begins its work, and in that little cell it reads the plans and specifications for the structure it is to build. With favoring conditions and no outside interference, it follows those plans without deviaton. It may develop and improve but it never originates. Life is a master builder, and a master preserver, for its work does not end with the building of the structure, it continues to preserve it. But where should we look for the architect,—the originator of those plans and specifications? Where, indeed, save in that Infinite Mind which lies back of the great law that rules the universe.

The conduct of mankind is regulated in accordance with the evidence of our senses, and, unless we reject all of the evidence thus furnished us, mind is only another name for the Infinite Intelligence that pervades the universe, and is also the directing power through which man exercises control over material things. True, the materialists tell us that mind has no existence save as a function of the body, or of one of the body's organs, and that thought is a mere secretion of the brain. Cabanis, a distinguished French physician, expressed the idea in this way. He said:

> "The brain is determined to thought, as the stomach is to digestion, or the liver to the secretion of bile."

The German, Voght, expressed the same idea in the following language:

> "Thought stands in the same relation to the brain, as the bile to the liver, or the urine to the kidneys."

Buchner, another German, says:

"Mind, like light, heat, electricity, or magnetism, is a movement of matter."

The late Ernest Haeckel, the famous German materialistic biologist, in his book "The Riddle of the Universe," says that neither mind nor soul have any origin, because sensation is an inherent property of all substance, and that conscious soul is a mere function of the brain. It is worth something that these gentlemen recognize that mind has an actual existence, even if they do degrade it to a mere function of one of the bodily organs. In animal physiology, a function of an organ of the body is simply its normal mode of action, and therefore necessarily involuntary and automatic. The bodily organs all have their functions. The heart, the lungs, the stomach, the liver, and the kidneys, have each their functions or their normal mode of action; and none of them can voluntarily refuse to act or change the manner of its acting. They act automatically. The action of the mind, therefore, according to these men, is simply the normal automatic action of the brain, as digestion is the normal and automatic action of the stomach. In animal physiology, a secretion is a substance existing in the blood, which is prepared and separated therefrom by glandular activity or by the action of the epithelial cells, as milk is separated from the blood and secreted by the mammary glands. To follow their argument to its legitimate conclusion, we might say that as all the organs of the body are built from the food we eat, and perform their functions by the power thus generated, and as all the bodily organs are produced from that same food, mind and thought really originate in the stomach, and that organ is the abiding place of the soul.

According to these learned gentlemen, therefore, the mind is a mere function of one of the organs of our body, as digestion is a function of another. Our much vaunted thinking and reasoning is only a secretion that oozes from our brain, as the tears ooze from our lachrymal glands while we weep over the dismal hopelessness and purposelessness of human existence as thus pictured by these scientists; and their erudite productions are no more than material exudations from their material brains.

The works of these materialistic writers, showing as they do that they are the result of much study, are alone sufficient to refute their conclusion. This is particularly true of the work of Haeckel. His work is not the production of a mere automaton. When we read the record he made of his lifetime studies in the field of biology, we know that it is not a record of the mere involuntary working of a bodily function. Every page evidences purpose and design; an individual and personal purpose and design that could not possibly find its origin in a mere bodily function. The existence of this purpose and this design is as obvious in that work as is the existence of purpose and design in the work of the Infinite Intelligence that is over all. The immediate and impelling power by which the various bodily functions perform their several offices, is life,—that force which builds the body. But life only follows the plan it finds in the germ with which its work begins. It

never changes that plan, or makes the mistake of developing the human germ into some other type of animal. Every function of the body is potentially present in the germinal dot from which the body grows. The various secretions of the different bodily organs are also automatically produced and their normal character is potentially determined when life begins its work with that germinal dot. The liver cannot secrete tears, nor can the lachrymal glands secrete bile. Whatever there is of purpose or of design that determines the character of these secretions, must be sought in the work of that Infinite Intelligence which lies back of the germinal dot. If thought is nothing but a secretion of the brain, we can no more originate and direct that secretion than we can originate and direct the secretions of other organs; there can be no such thing as an intention of thought, and our so-called reasoning is a mere involuntary discharge of an involuntary secretion, as free from inherent intention, or from voluntary and independent purpose, as is the urine or the bile. They tell us that the beginning of all organic life was in a germ or germs that in some way appeared in primordial slime. They also tell us that these germs have developed throughout countless ages into myriad forms of life, and that among these forms they find the physical man of today. They may be right as to this, for physical man is still "of the earth earthy", and can hardly deny kinship with the slime. Keeping their eyes on that slime of the distant past, and on the life force that stirred its depths when that germ appeared, they seek only in the dust of the ages and in that life force for the origin of all the qualities they find in the man of today. They might as well attribute the secret of Canova's genius to the marble of Carrara, or the inspiration of Michael Angelo or Raphael to the pigments they used. They remind one of Bunyan's "Man with the Muckrake". If they will but lift their eyes from the dust and study the harmonious rule of that power which governs the universe, they will find the source of the crowning glory of humanity.

> "The Heavens declare the glory of God, and the firmament showeth his handiwork. Day unto day uttereth speech, and night unto night showeth knowledge. There is no speech nor language where their voice is not heard."

As the mysterious thing we call "magnetism" may enter into the apparently inert needle of steel and give to it a new quality or power, and as magnetism's mysterious relative, electricity, when it is sent coursing through a wire, imparts to the filament in the bulb the power to emit light, so man, at some point in the course of his development, has had imparted to him a power beyond anything that can originate in that form of force we know as life. Life acts automatically, but this new power enables man to originate action,—to think, to reason, to decide, and to do. Common sense is a most excellent possession, and common sense would dictate that in searching for the origin of mind we should look where we know mind to be. One would not search for tropical flowers at the north pole, nor for icebergs at the equator.

In conclusion, my guess, as above indicated, is that life is the constructing and conserving force in nature, and that mind in man, in-

stead of being a mere exudation from a material brain, is that Infinite Mind itself shining through the clouds of matter, and gradually developing the brain as an instrument for its future use; that the limitations of our mental processes are due to imperfections in the instrument it uses, an instrument not yet fully developed. Imperfect as its manifestations are, I see in it that which thinks, which reasons, which plans, and which directs; that which inspires and lifts; that which creates the beautiful and majestic things the artist and the poet embalm in color and in words; that which makes great men, great leaders of men, great statesmen; that which makes men great in anything; that which reaches out into space, further than the most distant suns of which science tells us,—further, still further, until we feel there is no boundary in space; that which looks back through the record of the ages gone,—backward and still backward, until time disappears, and we feel there is neither beginning nor ending, only an eternal now; that by which we grasp the immensity, the majesty, the beauty, and the symmetry, of all, and which forces upon us the conviction, not that there is *a* God, but that God is.

ESTIMATING THE COMPARATIVE RICHNESS OF INDIANA.

STEPHEN SARGENT VISHER, Indiana University.

It is difficult to evaluate the many items which together make up the richness of a state, and hence carefully considered comparisons of the comparative wealth of large areas, as states, are few or lacking, although poorly founded assertions of superiority are common.

In spite of the great difficulty of arriving at a just statement of the richness of a state like Indiana it is very desirable that the citizens have a well founded idea as to the standing of their state.

My studies have convinced me that Indiana is one of the most fortunate areas in America. I doubt if another area of like size is permanently richer, except an area which would include a large part of Indiana. But what existing state is richer in proportion to size? Iowa is perhaps a better farming state, but she lacks many of Indiana's advantages. Illinois has Chicago, and more coal than Indiana but she is likewise much larger and has numerous difficulties and responsibilities which Indiana has to a lesser degree. Ohio, another fortunate state is inferior to Indiana in having a wide lake and a national boundary largely shutting her off from the north, a less central location and a larger percentage of rough land.

Indiana has a far smaller coal reserve than several states, but in the long run coal is less important than climate, topography, soil and a favorable location. Some believe that accompanying the practical exhaustion of coal, there will be an altogether different distribution of the industrial centers. For example, that the more important parts of our nation will then be near the Cascade Mountains because of the great water power resources there. However, I suspect that instead power will be brought to the places which have a favorable climate, fertile land, and already well established industries.

But now to consider how Indiana compares at present with other states. Indiana is 37th among the states in point of size. She is surpassed by many larger states when totals are concerned, but totals are often less significant than amounts in proportion to population or in proportion to area, or in proportion to needs.

The gross value of farm products affords one excellent basis for comparison between the states. In this respect, Indiana ranked eighth in 1919[1]. However, only three states ranked ahead of Indiana in the value of farm products in comparison to size. Iowa, the leader in 1919, produced only ten per cent more while Ohio produced only a trifle more per square mile than did Indiana.

The "gross value of farm products" is made up of crops, livestock products and animals sold or slaughtered. In respect to value of crops, although Indiana ranked thirteenth state in 1919, when allowance is made for comparative size, Indiana is seen to surpass all but Iowa, Illinois and Ohio. In livestock products, Indiana ranked eleventh but six

[1] Statistics given are all official census figures.

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of ten states ahead of Indiana are enough larger to fall behind Indiana when comparative area is considered. Indiana stands still higher in the value of animals sold or slaughtered, ranking seventh when size is ignored, but claiming third place when area is considered.

In respect to individual crops: Though often surpassed by five states, Indiana ranks with Illinois and Iowa as a corn state, when area is considered. Indeed, in average yield of corn per square mile, Indiana surpasses these states, as well as the other three—Missouri, Nebraska and Kansas, which often have more acres planted to corn than Indiana. In wheat production Indiana normally ranks eighth, but is usually exceeded only by North Dakota and Kansas in the average yield per square mile of total area. In oats production, Indiana ranks seventh, but fourth when area is considered.

Indiana is second in hog production, and in eggs; third in the average crop yield per acre during the poorest years; third in the average value per acre of farm land, and in the percentage of improved farms; third in poultry; and sixth in the dependability of crop yields from year to year. The only states which surpass Indiana in this very important respect are in the extreme East, on the Atlantic Coast.

Few people realize how large a total income is obtained from Indiana's forest trees. In 1919, Indiana marketed eleven million dollars worth of forest products, ranking nineteenth among the states. In proportion to area, however, Indiana ranked thirteenth.

The value added by manufacture (724 million dollars) was only a little less than the gross value of farm products, which was 782 million dollars in 1919. As a manufacturing state, Indiana ranked ninth among all the states in 1919. Indiana had more than two dozen manufacturers, yielding products worth over ten million dollars in 1919. The leading industries of Indiana according to the Census are: 1. Steel, forgings, etc., producing products worth 192 million dollars and giving Indiana third place among the states. 2. The Indiana products of the automobile industry had a value of 179 million dollars in 1919 and Indiana was surpassed only by Michigan in this respect. 3. The third industry in value of products, was the manufacture and repair of railroad cars, etc. The total for 1919 was 149 million dollars, and Indiana's rank was about fifth. Indiana ranked ninth in the value of the slaughtering and meat packing industry, with a value of 134 million dollars. However, if comparative area is considered, Indiana would surpass half of the eight states which have greater totals. Indiana ranked third in the production of agricultural implements in 1919. In the value of products of the canning industry, Indiana should take fourth place instead of sixth. Likewise, although Indiana was about eighth in the value of the products of flour mills and grist mills, she is enough smaller than the higher ranking states to surpass all but the leading state, Minnesota, in value per area.

In mineral products also, Indiana ranks high, second in the production of cement, fifth or sixth in coal, fourth in coke, fifth in brick and tile.

In brief, in spite of her comparatively small size, the 37th state in

this respect, Indiana ranks second in the automobile industry, in cement, and in flour and grist mill products, third in the steel industry, in corn and wheat production, and in animals sold or killed; fourth in the gross value of farm products, of crops, of livestock, of oats and of coke, and in the canning industry; fifth in meat packing and in coal mining; eighth in manufacturing; and thirteenth in forest products.

Conclusion: Indiana's high rank in these diverse but fundamental respects indicates clearly that our state is very rich. No other state is notably richer, in proportion to size and population. Although a few other states are richer in total wealth, they also have a larger population to serve and a larger area to cover. Furthermore, their sources of income are not so diverse as are Indiana's nor are the yields of their crops so dependable year in and year out.

Indiana's wealth is not of the short-lived kind; most of the state has very deep, fertile soil; the climate is excellent in many ways; and Indiana's central position is very advantageous. We need not be surpassed by Michigan, Wisconsin, or any other less well endowed state. We should lead.

THE SOUTHERN UTE INDIANS OF PINE RIVER VALLEY, COLORADO.

ALBERT B. REAGAN, Cornfields, Ganado, Arizona.

The Southern Ute Indians of Pine River Valley, Colorado, are the Moache and Capote divisions of the great Ute family. They were once very numerous and occupied portions of Utah, Colorado, and New Mexico, and possibly even a portion of Arizona, for in 1775 Father Escalante visited them in the region north of the Hopi villages in Arizona. They now number only 352.

Since 1863 they have occupied their present reserve and are now making rapid strides toward civilization, though they were slow in making the start. Today they live in modern houses and every family has its little farm on which grain, corn, fruit and garden truck are raised. They have done so well in recent years that in the Dry Farming Congress at El Paso in 1916, they carried off the Silver Cup Prize in competition with all the other Indians in the United States.

They still practice a few ceremonies and perform a few dances. Among the latter is the "Bear Dance", so-called because the Utes assert that the bear originated the ceremony in the long ago. It is performed in the early spring or the first days of summer and usually lasts four days. It is a big event and the Apaches, Navajos, Mexicans, and whites join with the Utes and all have an enjoyable time. Below is a description of one of these dances as given near Ignacio, Colorado, in June, 1917.

Preparatory to the dance, a level plot of ground was selected in a pasture near town, and a dancing field some 300 yards in diameter was laid off and inclosed in an artificial, upright hedge fence. Benches were placed within the inclosure along the northwest half of the fence for the men to sit on, the ground within the inclosure along the southeast sector being reserved for the women to squat. Within the inclosure on the west side a deep hole was dug over which an inverted tub was placed. This was then inclosed in a square-bench enclosure on which the musicians were to sit. Heavy oak sticks, two and one-half feet in length were notched in "washboard style"; some also had carved heads with eyes and mouth for the sounding end of the stick. Bones of suitable length and thickness were also secured for the rubbing process in the "music-making".

The dance was given only of afternoons until the fourth day when it lasted the whole day, followed by a feast.

When all was ready, the musicians, seven in number, seated themselves on the benches around the tub-drum and leaning their notched sticks so as to place the end farthest from them on the inverted tub-bottom with notches up, they began to sing a chant in the minor key. As soon as the song "had warmed up to a sufficient pitch", the musicians began to keep time by rubbing the bones up and down over the notched sticks producing a reinforced, ear-grating sound.

After the first song, a speech-prayer service was conducted by the chief of ceremonies. Then the women chose male partners by approaching and waving their hands toward the one of their choice. If a white man was chosen he was expected to pay for the privilege of dancing, and any one chosen was obliged to accept or get out of the enclosure. Preparatory to the dance the men and women lined up facing each other in column abreast, the women in one column, the men in the other. The members of each column held hands, one column taking two steps forward and the other two steps backward to the time of the music, then *vice versa.* Thus was the dancing kept up in a set and continued in each succeeding set till the closing dance the fourth day, the Indian women choosing a new partner for each set.

The closing set was an endurance test. It began the same as the others, but soon changed to a single couple's partner dance in which the partners held each other in a position similar to that taken in our waltzes; the step, however, was the same as before. This dance was kept up till the participants quit of exhaustion. One participant fell down in the dance and the medicine man used one of the drum sticks as a wand and collected the evil spirits on it and then sent them to the four winds; he laid the stick first on her feet, then across her hips, then across her breast, then across her back, and lastly on her head. Unless this was done, it was believed some misfortune would befall her.

After the close of the endurance fête, the chief medicine man took a cup and as he danced, he held it upward as an offering of thanks to the gods and as a prayer for rain. His dance was followed by two speeches by two leading men. Then a feast was set out for all, after which they returned to their respective homes, believing that the gods would bless them and give them a bountiful crop.

An interesting account of the habits of the Southern Ute Indians is given by Dr. Alex Hrdlika in bulletin 2, part 2, pp. 619-620, of the Bureau of American Ethnology.

TWINKLING STAR.[1]

ALBERT B. REAGAN, Cornfields, Ganado, Arizona.

Synopsis.

The Apache medicine girl Twinkling Star is dying of consumption. Medicine singings are held over her night after night. The magic, medicinal powers of the snake, frog, medicine god, medicine stick, and medicine cane are applied, but she gradually declines. The medicine game is then played to make her well, but the medicine man loses the game. The Gunelpieya Medicine Disk ceremonies are resorted to, and these are followed by the medicine dance. In the excitement, at the climax of this performance, Twinkling Star joins in the dance in hilarious action. She swoons and dies. A wild, indescribable scene follows. After the body is elaborately attired, it is carried to the mountain side and buried with her personal effects under a piñon tree. Her live stock is then killed and her tepee burned. This being done, the women wail and mourn for her at morning, noon and night for thirty days.

Characters.

1. Twinkling Star and the people about her tepee.
2. Chief Medicine Man F-4.
3. Medicine singers.
4. Gumwapah, an old medicine woman.
5. Clowns and ghost dancers and other medicine actors in the Gunelpieya Medicine Disk ceremonies.
6. Medicine dancers and assembled Indians.
7. Actors in the ceremonies over the dead.

Scenario.

Scene 1.—Twinkling Star, a young Indian woman, sits in front of her father's tepee coughing and showing every symptom of a person in the last stages of consumption.

Scene 2.—Subtitle: "Medicine Singing Performance."

Night comes on and the medicine people come to her tepee to perform over her. Among them is Chief Medicine Man F-4.

Scene 3.—The sick one reclines on a pine-twig mat by the fire within the tepee.

Scene 4. The medicine man enters, goes over to the side of the tepee by the central fire and doubles his feet under him in a sitting position near the sick one. He then bends his body over forward, places his hands claspingly over his face and forehead in the form of a sort of hood and begins to sing.

"Go away sick! Go away sick! Go away sick!"

[1] This scenario depicts the medical attention given Twinkling Star, an Apache girl, the death scene and burial ceremonies, as acted out by the Indians and witnessed by the author, in 1902.

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Scene 5.—The musicians enter and begin to beat tom-toms (pots with rawhide stretched over their open faces).

Scene 6.—The medicine man stops singing, spits in the fire, and sprinkles the sick one with cattail flag pollen. He then resumes his singing with posture as before.

Scene 7.—The medicine man produces a crudely made, striped, wooden snake. This he places in the hot ashes a moment. He then places its head on the afflicted parts of the bared body of the patient in four different directions, corresponding to the semi-cardinal directions. As he thus places it, he sings and points respectively to the gods who are holding up the four corners of the earth. He then burns the wooden snake, as he sends the evil spirits away with a hissing breath and looks with elevated face toward the northeastern heavens.

Scene 8.—The medicine man produces a wooden frog and performs with it same as he had performed with the snake in 7.

Scene 9.—The medicine man resumes his singing with posture as in scene 3.

Scene 10.—The medicine man produces a wooden carving, an effigy of his leading medicine god (fig. 1). This he places on the sick woman as he did the snake in Scene 7.

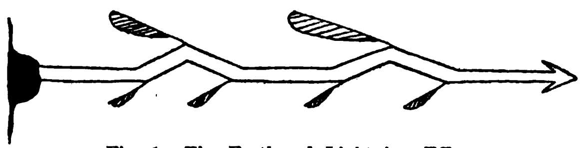

Fig. 1. The Feathered Lightning Effigy.

Scene 11.—He hides the medicine god in a niche in the rocks of a neighboring cliff.

Scene 12.—The sun comes up and the ceremonies cease. But the patient is worse.

Scene 13.—Night brings the medicine man and the musicians to doctor the sick one again.

Scene 14.—The medicine man sings over the sick one; the musicians beat the tom-toms.

Scene 15.—The medicine man performs over the sick one with five medicine hoops some two feet in diameter and colored to represent the colors of the rainbow, performing the same as he did with the snake in Scene 7.

Scene 16.—He then takes the hoops and hides them in a niche in the rocks on a nearby mountain side.

Scene 17.—He performs over the sick one with medicine stick (fig. 2) as with the snake in Scene 7 and then burns it.

Scene 18.—He performs over the sick one with a medicine cane as with the snake in Scene 7. He afterwards buries the cane in the floor of the tepee.

Scene 19.—Subtitle: "The Medicine Game."

He plays the medicine game (fig. 3) with four flat splints with a chosen partner. The sticks are bounced on a flat rock in the center of

a six foot circle of forty cobble-stones. The sticks falling with a certain side up are favorable to the recovery of the patient. Knowing that the patient will die, the medicine man plays to lose the game.

Insert: "The sick one grows steadily worse day by day."

Fig. 2. The Medicine Staff, with dangling medicine pouches.

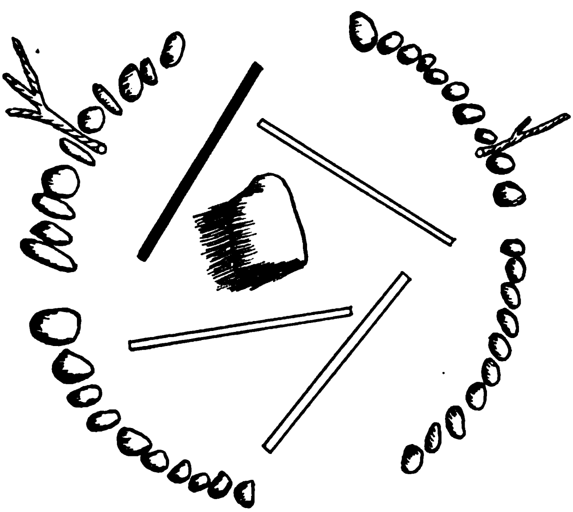

Fig. 3. Game Field of the Medicine Game, showing the "cobble-stone circle" and counting sticks in place showing the counts received (they are the sticks lying between the cobble-stones). The two wide spaces are designated "water". Should the tallies be such as to place a tally-stick in either of these spaces, the player loses all the points he has made in that game-count and, consequently, must begin the count again. The game sticks, as they have fallen within the circle in the cut, count the thrower two points. One hundred and sixty-four continuous points constitute a game.

Scene 20.—Subtitle: "The Gunelpieya Medicine Disk Ceremonies."

A horseman rides swiftly up the valley and summons the people to make a medicine disk (fig. 4).

Scene 21.—In the mid-forenoon the people assemble in a protected spot at the edge of the woods and proceed to make the likeness of the "Sun Father" on the ground in disk form, in accordance with the Indian belief. The drawing is some sixteen feet in diameter. It is the front view of the massive head, with a crown for a hat and the suspended "medicine squares" for a necktie. There is no nose, or neck, or body shown. The eyes and eyebrows are there as is the mouth. The latter is peculiar. The lips are in the form of a square set naturally with the face. They are parted showing the odd-shaped mouth. This is shaped like a diamond, or square, so drawn that each of its respective corners bisects a side of the square that forms the lips. From the mouth at

Fig. 4. A Medicine Disk, used at another, but similar, medicine performance.

the left there is supported a long stemmed pipe, on which is drawn the bolt lightning. And from each corner of the lips, as drawn, a funnel-shaped wisp of the sun's rays extends out into measureless space. The different parts of the drawing are variously colored in red, white, black, gray and green. The red coloring matter is made from ground up red sandstone; the white from ground up limestone; the green from crushed leaves; the black from pulverized charcoal; and the gray from a mixture of charcoal and limestone.

Scene 22.—The disk being completed, a canvas is stretched around it leaving a small doorway at the east side.

Scene 23.—Insert: "The sick one is to be presented to the drawing of the god of day; and he can either cure her or take her to his abode in the immensity beyond."

The actors come. Gumwapah, an old medicine woman carrying a dirty bowl partly filled with water, comes from a near-by wigwam; enters the medicine disk by way of the pipe stem; and, in a stooping position, passes around within it from left to right near its outer rim. As she thus moves around near the drawing of the outer circle of light, she takes a pinch of the coloring matter from each respective part of the drawing and puts it into the cup. Completing the dust gathering, she sets the bowl down in the upper corner of the sun's mouth and then passes out of the disk drawing by the way she came.

Scene 24.—The medicine men come with the patient from a near-by tepee. They are carrying her. They also enter the disk by the pipe stem. They carry her around the circle of the sun's rays from right to left; then to the center of the sun's mouth and place her upon it with face turned toward the afternoon sun.

Scene 25.—A medicine ghost dancer sallies forth into the open space from a nearby thicket. He is nude with the exception of a dancing skirt. His body is painted in white, and zigzag lines run up his arms and down his lower extremities to represent the blazing thunder bolt of the raging storm. He also wears a loose, sack-like cloth mask, on top of which there extends skyward a row of lath facing the front and so placed as to crudely represent the spread tail of a turkey. In addition, he carries a sword-like wand-stick in one hand and an old Indian knife in the other. Shrieking, whooping, and occasionally gobbling like a turkey, he crow-hops in a large circle around the drawing of the god of day and the sick one waiting to be cured, posing now and then in baboon style. Completing the circle, he makes a rush sidewise for the presence of the sick one like a male swine going to battle. Reaching her presence, he squats in front of her, sticks the knife in the ground by her side, places the wand on the afflicted parts of the sick one in each of the semi-cardinal directions, gathers the sick on the wand in this way, takes the wand up before his face, blows a hissing breath on it to drive the evil spirit "sick" away. He then gives a hideous, ear-grating howl, seizes his knife and gallops forth into obscurity.

Scene 26.—The chief medicine man enters the circle, and, taking a piece of green gourd rind in his hand, he rubs the sick one all over with it. He then daubs her all over with the muddied water from the bowl, the moistened dust of the drawing of the Father of the Day. This being completed, he places the gourd rind against the lower end of the sick one's breast bone and sings a song to the gods to help her, the musicians with tom-toms aiding him in the singing.

Scene 27.—The sick one is carried from the medicine disk inclosure; and the medicine drawing is at once obliterated.

Scene 28.—Subtitle: "The Medicine Dance."

A huge fire is kindled in the center of a level area among the hills. Here are assembled all the people of the valley. Around the fire in a great circle they are squatted on deer skins. At one end and within the circle are the doctors and musicians; but the dancers and sick one have not yet arrived.

Scene 29.—We find the sick one in a near-by improvised tepee. She is lying face down on a mat and medicine women are rubbing her back with scorching, smoking piñon twigs. Time and again she faints, only to have the twigs snatched from the blaze quicker and applied to her back. But the dancers are coming.

Scene 30.—The sick one is carried to within the circle of human beings and placed on the opposite side of the fire from that occupied by the musicians.

Scene 31.—The tom-toms begin to beat. The chief medicine man leans his body forward and covers his face with his hands, holding them in a sort of hooded position. The doctor and the musicians commence the monotonous chant, as they wave their bodies to the time of the music. The sick one looks expectant. They are coming, the ghost dancers of the gods. They enter the circle of light from the northeast. There are five of them. Four of them are attired as was the dancer in the afternoon (Scene 25); but now each carries a wand in either hand. The fifth actor is a clown. He is attired only in breech-cloth and is masked with a horned mask. He carries a wand in his left hand, a three-pronged stick in his right. Around the central fire, the musicians and the sick one, they dance in single file for a considerable time, the four dancers posing now and then and gobbling the while like a turkey, which they are supposed to represent; the clown at times cuts capers and tumbles around over the ground to amuse the populace.

At last they approach the sick one in single file. Then acting like a bird when it has seen something it is rather afraid of, they gobble and dance backwards from her presence in single file. Again and again they approach her, each time getting a little closer to her. Finally the foremost dancer of the line leaves his fellows, trembling, prancing, and dances to the feet of the patient. She sits up. He leans over her. He places his wands crossed on her head, on her back, on her lower extremities, and on her chest. Then he raises the still crossed wands toward the northeastern heavens and, as he parts them with a sweeping motion and emits a hissing breath from his mouth, he scatters the "sick" toward the four winds. And with a shrieking howl, he canters off into the blackest darkness.

The rest of the dancers follow in succession and perform in a similar manner, as does the clown also, except that he acts the clown as well as a medicine dancer. His principal feat is to kill the "sick" by spearing it with his trident after he has collected it on his wand. His performing completes the first of this setting. There are three more scenes in it, all of which are similar to the one just described, except that in scene two the sick one faces the southeast and the actors approach her from that region; in scene three the sick one faces the southwest, and the dancers the northeast; and in the fourth scene she faces the northwest, the actors the southeast. But they are gone and another set of actors are taking their places.

Insert: "Throughout the night dance ceremonies like the above are kept up till thirteen consecutive dance scenes are completed. Then comes the closing scene."

Scene 32.—As the sun begins to show his advance fingers of gorgeous colored light over the eastern mountain peaks, the clown wakes all the sleepers with his trident and compels them to stand up. The chief medicine people sprinkle all with sacred meal. Every one takes one more drink of Indian whiskey (twiswin). The medicine dancers approach the sick one again. As they perform, every one joins in a straight backward and forward dance within the circumscribed area. The excitement becomes intense. They all shriek and shout till the hills re-echo it again and again; and the drummers pound the tom-toms till it seems as if the very poles of the earth have thundered. The sick one makes one supreme effort to rise and join in the dance but she has not sufficient strength. They lift her to a standing position, they sprinkle her with the sacred dust, they rub her back and her chest with scorching fir twigs, they support her in a dancing position. She makes one more heroic effort to dance and become well. Greater and greater becomes the excitement. The chief medicine man prays louder, the shrieks and shouts of the dancers become deafening. The crisis comes. In the excitement, under the influence of the hypnotic spell, the sick one forgets her ailments. She dances. She takes a medicine hoop in each hand. She lifts them high above her head. She leaps. She crow-hops. She poses. She struts around the great fire like a turkey. She calls the gods by name. She shrieks, swoons and dies.

Scene 33.—Subtitle: "The Ceremonies over the Deceased."

Words can not describe the scene that follows. The men weep, the women wail with the hideous coyote yelping wail. They pull their hair out by handfuls, then rend their apparel and destroy their property at hand. They make a rush to see the corpse. They trample over each other, and it is with difficulty that they are kept from crowding one another into the great fire.

Scene 34.—They carry her to the nearest wigwam; strip, wash, and dress her; bead her with all the beads of the clan; put wristlets upon wristlets on her wrists; and roll her in her best robe.

Scene 35.—They take her and all her personal belongings to the mountain side and bury them beneath a piñon tree.

Scene 36. They then return to the village and destroy everything which belonged to her, both animate and inanimate, together with her tepee (the horses, cattle, dogs, were stabbed to death; the other property was piled up and burned).

Insert: "The property of the deceased is destroyed that it may be with her in spirit in the land of bliss."

Scene 37.—Subtitle: "For thirty days the women mourn and wail for the dead."

Then for thirty days the women go to some secluded place and wail and mourn for Twinkling Star at morning, noon, and night.

HISTORY OF THE LAKES NEAR LAPORTE, INDIANA.

W. M. TUCKER, Indiana University.

In October, 1921, the writer's attention was called to the recession of the lake level in the vicinity of LaPorte, Indiana, by an appeal from the Park Board of LaPorte to the State Conservation Commission for suggestions as to the cause of the recession and means of raising the lake level. Since that time I have spent about three weeks in the field about LaPorte and have found a peculiar and very interesting problem. On my first visit to LaPorte I was accompanied by Prof. Will Scott of the Zoölogy Department of Indiana University and on my third and last visit I was assisted by Mr. W. A. Thomas, a student of Geology at Indiana University. I wish to acknowledge the services and suggestions of these men and also Mr. Maurice Fox, President of the Park Board of LaPorte; Dr. W. N. Logan, State Geologist; Mr. Burtis Thomas, City Engineer of LaPorte; Mr. Robert Day, Assistant City Engineer; Mr. W. A. Cummings, Park Superintendent of LaPorte; Messrs. J. W. and Archie Good, well drillers of LaPorte and many others whose suggestions and services were of value.

PHYSIOGRAPHY AND GEOLOGY OF LAPORTE COUNTY.

The physiographic conditions of LaPorte County are dominated by the influence of the Wisconsin glaciation. Mantle rock derived from glaciation overlie the Devonian limestones and shales to a depth of 100 to 250 feet or more. There are no bed rock exposures in LaPorte County. By reference to figure 1, the type of surface rock are evident. The southeastern 60.1 per cent of the county is an old lake flat. It is now called the Kankakee valley or Kankakee lowland. This region slopes gently toward the south from an elevation of somewhat less than 800 feet on the north to the Kankakee River somewhat above 700 feet on the south. The average slope of this region is about five feet per mile. Gravels and sands on the north merge into finer sands, clays and peat on the south. Great areas along the Kankakee were covered by swamp until recent drainage projects have reduced them materially. Considerable swamp land still prevails, however.

Lying northwest of this lake flat is the great Valparaiso moraine. This area comprises 29.6 per cent of the county. The crest of this moraine is represented in general by the divide on figure 1 and that part lying north and west of LaPorte is shown accurately. This crest is undulating reaching elevations about 950 feet and seldom reaching lower elevations than 900 feet. The south margin of the moraine has an elevation of about 800 feet, usually slightly less. The north margin has an elevation of from 650 to 680 feet. Thus the north slope is much steeper than the south slope. The surface of this moraine is of the knob and basin character typical of well developed morainic regions. The north slope is undergoing severe stream erosion where the tributaries

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of Trail Creek have invaded it. The south side has a few small streams which empty into swamps or small lakes but the tributaries to the Kankakee have not invaded this morainal area. The Little

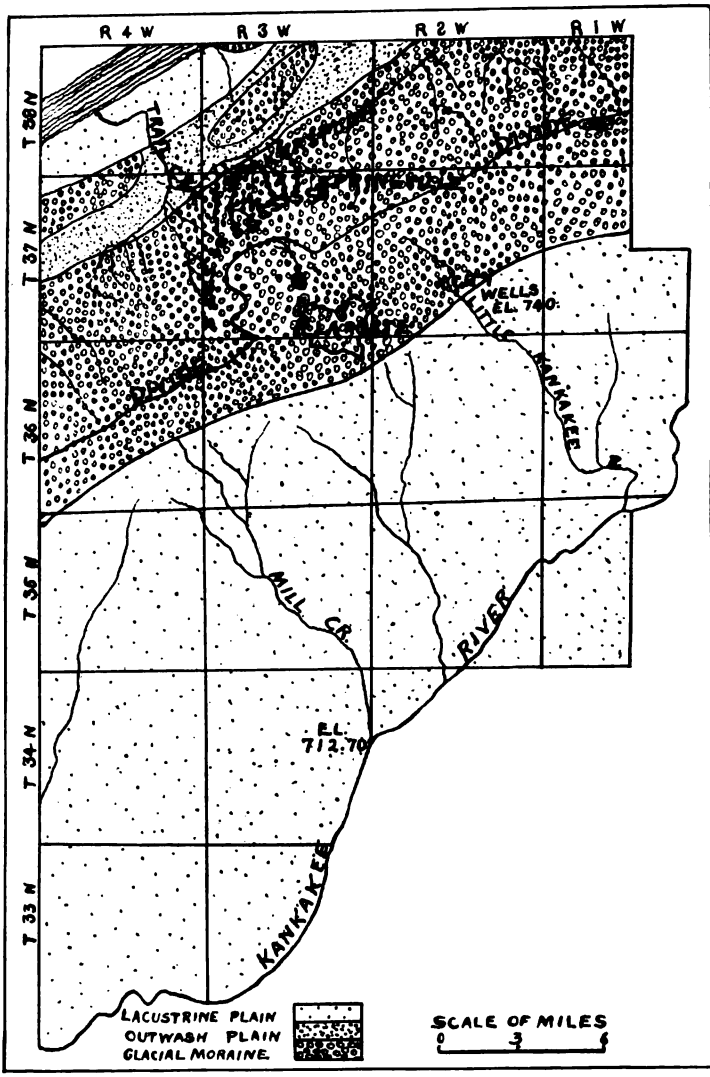
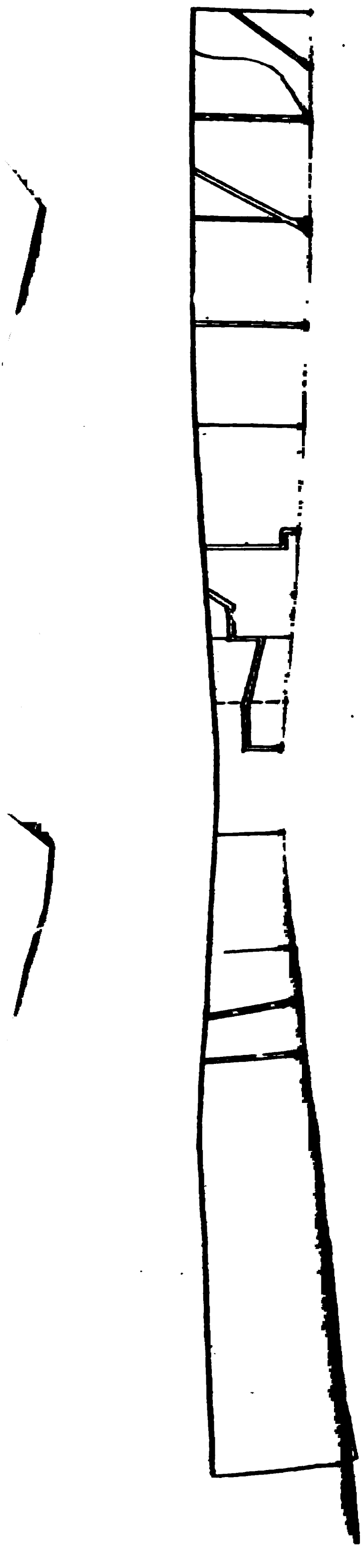


Fig. 1. Map of LaPorte County, Indiana, showing glacial deposits and other data. (After Leverett.)

Kankakee, east of LaPorte, is an exception to this rule. It rises in a glacial stream valley which lies within the moraine. The moraine is composed of sand and gravel with occasional lenses of clay. According



to Mr. Leverett[1] this moraine is predominately clay west of Valparaiso and sand and gravel east of that point.

Four other small areas lie to the northwest of the Valparaiso moraine in LaPorte County. These are a belt of outwash about two miles wide comprising 3.9 per cent of the county, small patches of moraine comprising 1.8 per cent, a lacustrine plain, part of the bed of Lake Chicago comprising 2.8 per cent and a part of Lake Michigan comprising 1.8 per cent. Sand dunes have encroached upon much of the land portions of these areas. Since these areas have little to do with the problem of the LaPorte lakes they will not be discussed in detail.

Origin of Lakes. Three types of lakes occur in LaPorte County. Those which lie in the Kankakee lowland are remnants of the great marginal lake which once occupied this area. Those which lie within the Valparaiso moraine are principally of the irregular type of lake which occupy the irregular depressions left by glacial deposit. There are probably some kettle hole lakes which are formed by melting of buried masses of ice within the moraine. This type of lake is small, nearly circular and deep. They are usually closely associated with the irregular type and are sometimes hard to distinguish from them. The group of lakes which lie west and north of LaPorte are of the irregular type. The group of lakes of which this paper treats specifically form a crescent partially within the city limits and partially on the northwest edge of the city. The limbs of the crescent point north and beginning with the northeasternmost lake we find, Lower, Clear, Lily, Stone, South Pine and North Pine, the last forming the northwest limb. On the northeast limb to the north of Lower Lake are three other small lakes, Lower and Upper Fishtrap and Horseshoe Lakes. These three lakes, however, are detached from the other groups by considerable divides and lie at considerably different levels so are treated only incidentally in this paper.

Status of Lakes at Earliest White Settlement. The six lakes named in the first group above are remnants of two lakes which existed when white settlers first came to this region. Lower, Clear, Lily and Stone lakes were then parts of one lake the extent of which is shown in figure 2. The elevation of this lake was about thirteen feet higher than the present level of Clear Lake or about 804 feet above sea level. The two Pine lakes were united at that time and the extent of this lake is shown in figure 2. The elevation of this lake was about twenty feet higher than the present level of North Pine Lake or about 809 feet above sea level. The divide between these two lakes was a low narrow ridge through which a channel was cut to allow the passage of a small steam boat. This boat was used to convey passengers from LaPorte to the Old Baptist Assembly ground on the north end of North Pine Lake where Pine Lake Village now stands. This steamer discontinued operation about forty years ago. During these early years Clear Lake had an outlet overland through the city of LaPorte somewhat north of the business section. This outlet ceased to flow forty or fifty

[1] Monograph LIII, U. S. Geol. Surv.

years ago according to the testimony of early settlers. Thus the decline of the lakes began long ago. However, the old shore lines, with their small terraces and small wave-cut cliffs, on which stand large trees whose lake side roots are deformed by ice and wave action, remain as mute testimony to the survey of 1829 when the extent of these lakes was as shown in figure 2.

Relation of Original Lakes to Present Lakes. Since the overland channel of Clear Lake has been closed the entire drainage of these lakes has been underground. A survey of 1847 shows the area of the lakes very greatly reduced from that of 1829 and the area at present is much smaller than that of 1847. The areas of the two lakes shown by the survey of 1829 and the areas of their present remnants as determined by planimeter from figure 2 are as follows:

North Lake of 1829	1.388 sq. mi.	North Pine Lake	.167 sq. mi.
		South Pine Lake	.275 sq. mi.
		Total	.442 sq. mi.
		Per cent of former lake	31.4
South Lake of 1829	1.317 sq. mi.	Stone Lake	.196 sq. mi.
		Lily Lake	.020 sq. mi.
		Clear Lake	.135 sq. mi.
		Lower Lake	.035 sq. mi.
		Total	.386 sq. mi.
		Per cent of former lake	29.3

From this we find that the areas of the two original lakes were very near the same and that the present remnants are not far different from each other, each representing about 30 per cent of the original. The levels of the remnants are fairly uniform. It is interesting that North Pine Lake is the lowest of the group and each lake of the crescent is slightly higher until Lower Lake at the other end of the crescent which is the highest. The following figures show the elevations of the various lakes as determined by Burtis Thomas, City Engineer of LaPorte, in December, 1921, and my own check on North Pine and Clear lakes in June, 1922, during a severe drought:

Lower Lake	792.75 feet	(Thomas)		
Clear Lake	791.76 feet	(Thomas)	791.62 feet	(Check)
Lily Lake	791.31 feet	(Thomas)		
Stone Lake	790.40 feet	(Thomas)		
South Pine Lake	789.58 feet	(Thomas)		
North Pine Lake	789.31 feet	(Thomas)	788.59 feet	(Check)

Figure 3 shows the elevation of Lily Lake from 1898 to 1914, inclusive. The record of the lake level was kept by the city waterworks employes for each day during this period. The elevation indicated for any year on this graph was derived by averaging the level readings for the first day of each month during the year. The monthly fluctuations were slight so that this gives a comparatively accurate elevation for the year. To convert these readings to the datum of sea level add 762.32 feet. This graph shows that Lily Lake fluctuated in this period

between low level of 29.42 feet (791.74) in 1901 and high level of 33 feet (795.32) in 1909. At the beginning of the period the lake stood at 793.19 feet and at the end at 792.79 feet. The average for the whole time was 793.13 feet. These elevations compared with the elevation of 791.31 feet late in 1921 shows a decline of less than two feet since 1898. Thus the general decline in Lily Lake has been comparatively small since 1898 if the records are all correct. Records upon other lakes are not available except occasional records upon Clear Lake which have been kept by Mr. W. A. Cummings, Park Superintendent, who asserts that Clear Lake has declined five feet or more in the last eight years.

Relation of Lakes to Ground Water Table. This group of lakes has no inlets except sheet drainage of very small areas and has no outlet. Therefore the lake levels are evidently maintained by ground water.

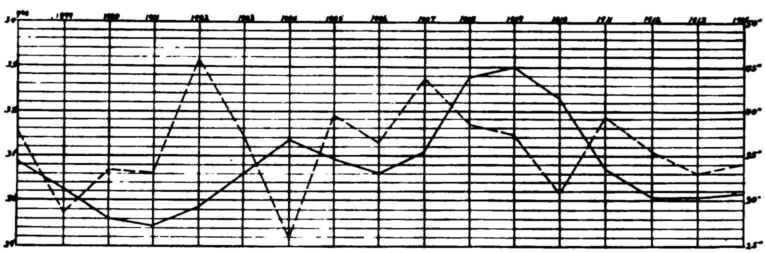


Fig. 3. Graph showing relation between the rainfall and the level of Lily Lake, Laporte, Indiana, from 1898 to 1914. Rainfall shown by broken line and referred to inches at right. Lake level shown by solid line and referred to feet at left. Datum of city bench mark.

The lake levels stand at the level of the water table. They rise and sink with the water table. So-called airholes in the ice in winter indicate that there are springs within the lakes which means that there is addition to the lakes by ground water. The mean annual rainfall at LaPorte is 36.83 inches[2], and the annual evaporation from free water surfaces is about 34 inches[3]. Thus, it is evident that these two factors almost balance each other with a small margin in favor of the increase of lake volume. Also, since there is a constant decline of lake level it is evident that there must be a loss through ground water movements.

Inasmuch as the movements of ground water are dominated by static head or steepness of slope and porosity of the material through which the movement takes place, the slopes to various possible outlets for the underground water from these lakes have been determined. These slopes are indicated in the following table.

[2] Condensed Summary of Climatological Data for 1915 by J. H. Armington, Indianapolis, Indiana, U. S. Weather Bureau.

[3] Russell: Monthly Weather Review, Dec. 1904.

TABLE 1. Elevations of low points about Clear Lake in relation to the elevation of Clear Lake, and the fall per mile.

Point	Elevation, ft.	Fall from Clear Lake, ft.	Distance, mi.	Fall per mile ft.
Clear Lake	791.62	....	....	....
Outlet of main sewer	769.77	21.85	2.75	7.94
Kankakee River at mouth of Mill Creek	712.70	79.92	15.00	5.33
City wells in Little Kankakee Valley	740.00	51.62	3.87	13.34
Springs north of divide near Springville	724.00	67.62	4.00	16.90
Pine Lake	788.59	....	....	....
Springs	724.00	68.59	3.00	22.86

Note: The last two show same relation between Pine Lake and Springs north of divide.

This table shows that the static head in feet per mile from Clear Lake to the springs north of the divide is slightly greater than that to the city wells which is the greatest to points south of the divide. The static head from Pine Lake to the springs is much greater than from Clear Lake. Since the material toward the north in the moraine is coarser than that at the edge of the moraine on the south, both slope and porosity indicate that the loss of water from the lakes is mainly northward. Clear Lake seems to be near the ground water divide and probably loses water in both directions.

Hypothesis of the Actual Water Loss from Lakes in Ten Years. The data concerning the actual decline in lake level for the past ten years is somewhat contradictory. Figure 3 shows Lily Lake to have been 793.19 feet elevation in 1898, and 792.79 feet in 1914 while the elevation at the end of 1921 was 791.31. These data indicate less than two feet fall since 1898. On the other hand the data collected by Mr. W. A. Cummings at intervals of a year or less for seven or eight years indicate that Clear Lake has declined five or five and a half feet in that time. The testimony of reputable citizens seems to bear out Mr. Cummings' data. These citizens point out definite points along the shores of Pine and Stone Lakes where the water stood ten years ago and these points are invariably about five feet above the present water level. It may be that the bench mark from which the data on Lily Lake was taken was not accurately located and was considered several feet lower than it actually was. This seems probable for it is not reasonable to think that Lily Lake was lower in that time than were the other lakes which would be the case if we recognize Mr. Cummings' data and the

testimony of citizens as authentic. However, the data on Lily Lake can be considered authentic so far as fluctuation is concerned.

The decline of five feet in the level of this group of lakes has greatly reduced its area. By estimate the present area is slightly more than half the area when the lakes stood five feet higher. If we consider that area to have been twice the present area it gives us a working basis to determine the actual loss of water in the ten years. The area of the present lake surface is .828 square mile. The former area if twice as large was 1.656 square miles. The average area for the ten years has been 1.242 square miles, which is 34,624,972.8 square feet. The volume on this average area to five feet deep is 173,124,846 cubic feet, the water loss in ten years. Thus, the loss per year has been on the average 17,312,485 cubic feet. This loss has been much more rapid than in the preceding years according to the testimony of citizens and according to the record kept at Lily Lake. While the consistent loss since white settlement of this region can be explained by deforestation and systematic drainage of the land, the increased decline within the last ten years is no doubt due to the installation of the sewage disposal system in the city of Laporte.

Apparent Relation of Lake Level to Ground Water Level Prior to Installation of Sewage System. When white settlers came to this region and for a long time thereafter Clear Lake drained eastward through the present city of LaPorte. During that time Clear Lake stood at a lower level than Pine Lake. This is shown by the levels of the old shore lines. Even at that time, however, there was underground drainage from Pine Lake through the Valparaiso moraine to the springs whose location is shown in figure 1. There is every indication that this drainage existed because of the steep gradient shown in table 1. Some idea of the drainage of the region north of these lakes and no doubt of the lakes themselves may be gained from observations at Harding Pond, Section 22. Considerable areas north of this pond are drained into it by tile drainage, one an eighteen-inch tile. During heavy rains this tile and others flow full into the pond and fill it up to a certain level above which the lake does not rise. Neither is there indication of water entering Pine Lake from this pond. The two are separated by a divide over fifty feet above Pine Lake. The distance from the pond to Pine Lake is about one-half mile and the difference in elevation 10 feet. Thus the gradient from Harding Pond to Pine Lake is 20 feet per mile but the springs north of the moraine are 75 feet lower than the pond and two and one-half miles away. Thus the gradient to the springs is 30 feet per mile.

The peculiar topography of this moraine with its abrupt northern slope leaves the whole southern slope perched so high above it that the tendency of the ground water below lake level is to pass beneath the moraine and appear at the springs. There are no large springs on the south side of the moraine. The material of the moraine is principally gravel and sand while that of the Kankakee lowland is fine sand and clay. There is every evidence that there is a deep seated underground drainage even from the Kankakee valley itself toward Lake Michigan.

Figure 4 illustrates the general idea. In order to prove this point a well test was made to determine the direction of ground water flow on the north shore of North Pine Lake at the point indicated by the letter W in figure 2. The point selected for the test was located fifty feet from the present lake shore, about five feet above present lake level on the old lake bed. A three-inch well was sunk to a depth of twenty-nine feet, which brought it to the level of the deepest point in Pine Lake. The deepest point in Pine Lake was 24 feet, located three hundred feet directly out from where the well test was made. Using the three-inch well as a center and a radius of six feet, a circle was described. On this circle at the cardinal and intercardinal points two-inch wells were sunk to the same depth as the three-inch well. The water rose in these wells to various heights from 2.73 to 3.08 feet below lake level. This circumstance proved that the ground water was not moving toward the lake at the surface of the lake. Some of the wells

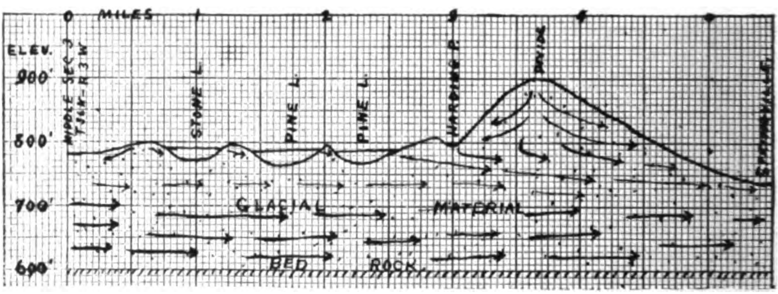


Fig. 4. Cross-section from middle of section 3; T. 36 N., R. 3 W. northward through Stone and Pine Lakes and Harding Pond, to Springville, showing probable ground water movements.

had clay pockets in the drilling and these wells stood at the highest level. All the wells were in gravel at the bottom.

At six a. m., July 4, 1922, the center well was charged with fluorescein, which colors the water a vivid green. Samples were taken from the outer wells each hour during the afternoon. At 7:00 p. m. a faint color was detected in the northwest well which became distinct at 7:15. Thus the ground water at that point was moving northwestward at the rate of six feet in thirteen hours, 11 1/13 feet per day. If this rate is uniform the time necessary for it to travel to the springs north of the divide is almost four years. This is rather rapid for ground water flow but the rapidity is due to the gradient of twenty-two feet per mile and the coarse sand and gravel through which the flow occurs.

The result of this test when associated with the fact that the lake levels are successively lower from Lower to North Pine and that there are overland channels which flow from Lily to Stone and from Stone to South Pine part of the year leaves no room to doubt that the principal ground water drainage from the lakes is from North Pine northward.

Springs Between Springville and Bakerspoint. A careful examination of the springs north of the moraine was made. The springs issue from the hill slope in bogs which sometimes cover several acres. Within these bogs the whole surface is filled with water and trembles as one steps upon it. In wet weather it is impossible to walk across them. The highest of these bogs was at an elevation of about 724 feet. From the bogs the water immediately forms a definite stream which flows down a steep slope until it joins Trail Creek. The seven springs shown as tributary to the east fork of Trail Creek (figure 1) discharged on June 22, 1922, 2.8628 cubic feet per second. This measurement was carefully made by weir and calculated by Francis' formula. The western one of these springs was by far the largest and discharged 1.75 cubic feet. No measurements were made on the springs tributary to the west fork of Trail Creek but the two forks are not far from the same size. The measured discharge amounts to 90,181,260 cubic feet per year. From the topography of the region it appears that about twelve square miles drain through the moraine in the vicinity of LaPorte. The discharge of the springs would account for about three and one-half inches of rainfall over this area. Since no measurements were made on the springs on the west fork of Trail Creek that discharge would account for considerable more. Since the rainfall is about thirty-six inches and the run-off usually about 25 per cent to 35 per cent, the amount to be accounted for would be about 9 to 12 inches. Therefore it is evident that these springs account for a considerable percentage of the drainage of this region.

Figure 8 has already been discussed to some extent on page 86 of this paper. The rainfall data shown in this graph was taken from reports of the United States Weather Bureau for LaPorte and are referred to inches on the right of the graph. It will be noticed that the lake response to heavy or light rainfall occurs two years later. An analysis of the graph shows an interesting relation. Low rainfall occurs in 1899 and low lake level two years later; high rainfall in 1902 and high lake level two years later; low rainfall in 1904 and low lake level two years later; high rainfall in 1907 and high lake level two years later; low rainfall in 1910 and low lake level two years later. Two slight contradictions to this response occur. A slightly diminished rainfall in 1906 has no corresponding depression of lake level in 1908 and relatively high rainfall in 1911 is not succeeded by high lake level in 1913. The latter case can be explained by the fact that the city water was drawn from the lake from July, 1908, to November, 1912. This fact may also account for the rapid decline of the lake from 1909 to 1912. The responses are too regular to be accidental and there must be some cause for it.

Hypothesis to Explain Responses of Lily Lake Level to Rainfall. The response of Lily Lake and probably of the whole system to the rainfall cannot be explained by the influence of any condition near at hand. While the actual movement of ground water from the crest of the moraine north of the lakes to them, if such movement takes place, would probably require two years, yet the rise of the water table at that point would show its influence much sooner. It is my opinion that

this response comes from a stimulus in the great morainic area of Steuben County and vicinity. Figure 5 shows the general idea. It is an interesting thing that artesian wells occur at many points between Steuben and LaPorte Counties. At South Bend there is a lens of impervious clay as shown in figure 5. A well drilled into the gravel beneath this clay will overflow in the lowlands along the St. Joseph River while a well sunk into the gravel above the clay will not overflow. In other places in this vicinity the same condition exists. The same influence communicated to the bottom of the lake system at La Porte would influence its level. The position of these lakes at the edge of the great clay deposits of the Kankakee lowland would account for the hydrostatic head by which the lake level is sustained slightly above this lowland. The response to the static influence from this great distance would lag far behind the stimulus. I know of no experiment or investigation which has ever been made to determine the rate of response of stimulus from hydrostatic head through rock. No conclusive

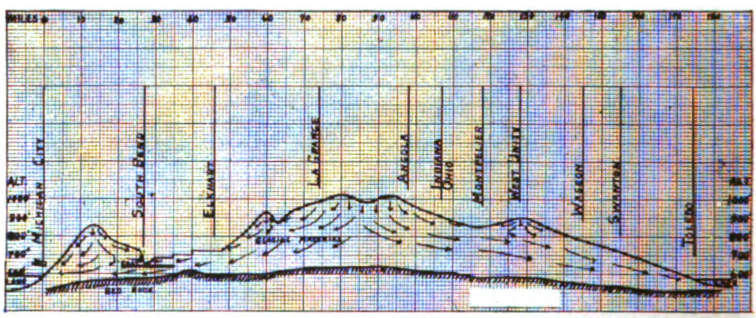


Fig. 5. Cross-section profile from Lake Michigan to Lake Erie showing major ground movements as dominated by major relief features.

statement as to the cause of the response shown in figure 3 can be made, but as before stated the responses are too definite and persistent to be ignored.

Apparent Effect of Installation of Storm Sewage System in LaPorte upon the Lakes, with Explanation. The storm sewage disposal system of LaPorte was constructed in 1912-13. The extent of the main lines of this system is shown in figure 2. Laterals extend to all parts of the city along these mains. All that part of the system north of the junction of the Fifth Street main with the main sewer line is above the level of Clear Lake. Following the installation of this system there has been a rapid decline in the level of the lake system. As previously stated, Mr. W. A. Cummings, Park Superintendent, has determined this decline to have been about five and one-half feet in eight years. Because of the coincidence of the beginning of the rapid decline of the lake level with the installation of the sewage system it is apparent that they are related.

The soil underlying the city of LaPorte is principally sand and gravel with small amounts of clay. Formerly much of the water which

fell in the city as rain entered the soil and became ground water. Thus, the water table was held up. After the installation of the sewage system the storm water was drained directly from the streets into the sewers. As a result there was a loss of water to the water table and it declined. Mr. J. W. Good, well driller of LaPorte, stated that he finds the water table about seven feet lower now than at the time of the installation of the sewer system. He states that the water table is now from twenty-eight to thirty feet beneath the surface of the city. The city bench mark on the court house lawn is at 812.32 feet elevation. Therefore the water table, according to Mr. Good, is at 782.32 to 784.32 feet elevation. If we consider the present water table as being at 783.32 feet elevation in the business section of LaPorte, seven feet lower than in 1913, and Clear Lake at 791.76 feet elevation or five and one-half feet lower than in 1913, we have the following comparison of levels:

	Clear Lake Level	Water Table Level	Difference
1913....................	797.26 feet	790.32 feet	6.94 feet
1922....................	791.76 feet	783.32 feet	8.44 feet

If we now consider the business section of LaPorte as one-half mile from Clear Lake, we find that the fall of 6.94 feet in the half mile is practically the same as the fall of 13.3 feet per mile toward the city wells (see page 88). By the installation of the sewage system the water table was lowered about Clear Lake, thus steepening the water table slope. This slope is still steeper than it was before the installation of the sewage system, so it may be that Clear Lake will decline further. Since the supply of water to the lakes was not increased when the sewage system was installed and the water table lowered on this side of the lake it serves the same purpose as removing a retaining wall from the side of a pond except that the response is slower due to the very slow movement of the ground water.

Proposed Plans for Restoring Lake Levels. On page 89 the average loss of water per year from the lake system for the last ten years is given as 17,312,485 cubic feet. Any means of restoring the lakes to their former level must therefore furnish at least this much water. Two plans are suggested. The first is to reverse the storm sewage of the city into Clear Lake. All of the system north of and including the Fifth Street sewer could be reversed. The area drained by this part of the system is about two square miles and the annual rainfall on this area slightly more than thirty-six inches. If we consider that the sewers carry away one-tenth of the water which falls within the area drained by them the amount disposed of during the year would be 16,727,040 cubic feet or almost enough to supply the deficiency. Since it is highly probable that much more than one-tenth of the rainfall is disposed of by the sewers and since the average loss per year to the lakes is probably considerably over-estimated, this reversal of drainage would probably be sufficient to prevent a further decline of lake level and also tend to raise the level.

A second plan is to drain areas of the morainic area north of the lakes into them. As previously pointed out, there is now little of this area draining into the lakes. However, between the lakes and the crest

of the moraine there are about 3,500 acres which could be drained into the lakes. Three lines of drainage are suggested and shown in figure 2. The eastern line of drainage beginning in section 14 would drain an area of about 1,000 acres without laterals and possibly half that much more by lateral connections. This drainage introduced into Lower Lake would silt it up and gradually reduce this lake to solid ground, which would be highly desirable, since Lower Lake is now virtually a swamp and nobody is interested in restoring it. This would admit the drainage into Clear Lake virtually free from sediment. The second line of drainage in sections 21 and 22 has already been surveyed by Mr. Thomas, City Engineer of LaPorte. It is proposed by Mr. Thomas to tunnel about 1,600 feet from Harding Pond to Pine Lake. This line of drainage would drain about the same amount of land as the former line. The third line of drainage in sections 20, 29 and 33 would drain a smaller area. The total area drained would be not less than 2,000 acres and if fully developed about 3,500 acres. The slopes along the drainage lines would vary from 30 to 50 feet per mile. The discharge delivered by these drainage lines if properly installed would vary from 25 to 40 per cent of the rainfall. This would be from 9 to 15 inches per year from the area. If the higher estimate of 15 inches from 3,500 acres is considered the discharge would be 190,575,000 cubic feet per year. If the lower estimate of 9 inches from 2,000 acres be considered the discharge per year would be 65,340,000 cubic feet. Even the lower estimate is 3.7 times the yearly loss of water from the lakes and the result of this drainage would be the immediate restoration of the lakes to higher levels.

The result of restoration of the lakes to higher levels would be to increase the ground water slopes from the lakes. In order to determine the amount of this increase we will consider a seven-foot rise in lake level. This would increase the slope from Pine Lake to the springs from 68.59 feet to 75.59 feet, an increase of 10.2 per cent. The increase from Clear Lake east to the city wells would be from 51.62 feet to 58.62 feet, an increase of 13.5 per cent. Since the movement of ground water depends upon slope and the porosity of the rock, and since the porosity would be unchanged, the increase in ground water loss would be from 10.2 to 13.5 per cent. If we consider this to be 12.5 per cent the estimated loss of 17,563,392 cubic feet per year would be increased to 19,758,816 cubic feet. This would still make the estimated discharge to the lakes over three times the estimated loss from them. I am sure the loss in this case is over-estimated and the gain under-estimated so that these figures are very conservative.

Some minor advantages would be derived by carrying out the proposed plans. Considerable areas of fertile land would be drained and made suitable for agricultural purposes along each of the three proposed drainage lines. The water table would be restored under the city of LaPorte which would restore wells to their former levels and also be of great value to the vegetation of the city. Clear Lake, which is now in the last stages of lake existence and rapidly becoming an unsightly swamp, would be made a fine open lake which would add greatly to the health and beauty of the city.

ABANDONED CHANNELS IN RANDOLPH AND DELAWARE COUNTIES, INDIANA.

FREDERICK J. BREEZE, Indiana State Normal, Eastern Division.

Extending across the massive moraine which trends east and west through southern Randolph and Delaware counties and northern Wayne and Henry counties are four broad valleys which were lines of discharge from the melting ice of the Wisconsin glacier. This moraine, which belongs to the Bloomington morainic system, needs a local name, and in this paper it is called the Mt. Summit Moraine, after the village in Henry County which stands on its crest near the place where it bends to the southwest. The northern section of each of these abandoned channels holds a small stream which flows northward. The southern portion holds a stream which flows to the south. The divide in each valley is a broad, muck swamp. (Fig. 1.)

Starting from the east, the first channel is that occupied by the headwaters of Greenville Creek and Nolands Fork. The swampy divide lies just east of Crete, a small village on the Peoria Division of the Big Four Railroad. It can be well seen from the highway that runs through Arba, Crete, and Spartanburg. The second channel lies east of Modoc another village on this railroad. The east-west highway passing through Modoc and Lynn crosses this channel near the southern edge of the broad, swampy divide. South from this swamp flows a small stream called West River, a tributary of West White River. The third channel lies east of Losantville. A small tributary of West Whitewater occupies the southern part of this valley, while the northern part is occupied by Little White River. The fourth, and largest of these glacial channels extends from the vicinity of Muncie to Newcastle. In the northern part of this valley now flows Buck Creek, a tributary of West White River. The Southern part is traversed by one of the headwaters of Blue River (East White River). A tributary glacial channel coming in from the southeastern corner of Delaware County joins the main glacial channel (Buck Creek-Blue River Valley) at a point about two miles south of the Delaware-Henry County line. Prairie Creek occupies most of the length of this old channel.

A probable line of discharge of glacial waters lies about three miles west of the eastern-most channel. The northern part is occupied by the headwaters of West White River and the southern part by Greens Fork, a tributary of West Whitewater. The divide, however, is not in a well-defined channel and therefore it has been thought best not to consider it with the other four lines of glacial outflow which are so well defined.

A. J. Phinney, M.D., in his geological reports recognized these valleys as lines of discharge of glacial waters. Writing of these valleys in his *Geology of Randolph County*[1], he says:

"The streams which occupy these broad valleys could never have excavated them; in fact, until ditches were cut, they had not even made a channel for themselves. They evidently mark the course of

[1] Phinney, 12th Ann. Rept., Ind. Dept. Geology and Natural Hist. p. 180.

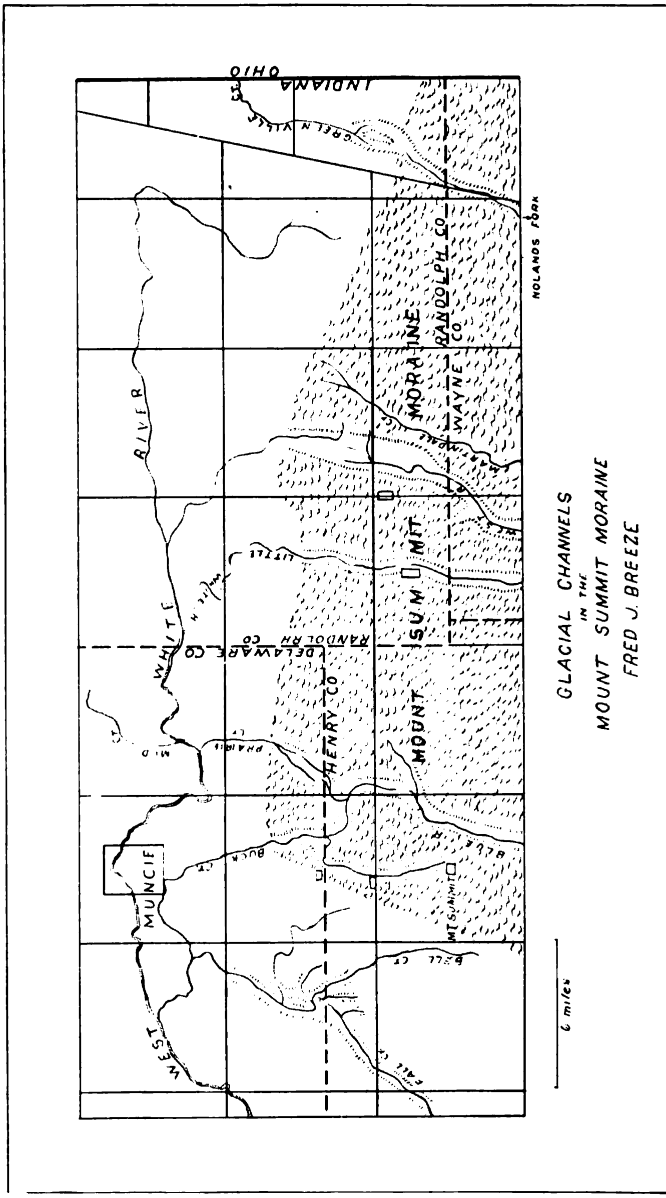


Fig. 1. Glacial Channels in the Mount Summit Moraine.

glacial rivers flowing from the northeast to the valley of the Ohio or the ocean."

Phinney[2] in describing the upper part of the glacial valley, which extends from near Selma, Delaware County, to the main glacial valley in which Buck Creek and Blue River now flow, says:

"Just west of Selma where crossed by the Bee Line Railroad it was deep enough and treacherous enough to swallow up their embankment when first built. This channel extends southwestward across the valley of White River and to the east of New Burlington into Henry County. Near the county line the channel, now called prairie, is filled up sufficiently to cause the water of Prairie Creek to flow northward to White River."

Arthur E. Taylor in *A Soil Survey of Randolph, Wayne, Henry, Rush, Fayette, Union and Franklin Counties*[3] in describing the Buck Creek-Blue River Valley, says:

"A very interesting problem in stream piracy was noted by the writer in the northern part of Prairie Township (Henry County), but time did not permit him to work it out in detail. * * * Blue River once entered Henry County two and a half miles east of Luray and drained a considerable area in southern Delaware County. Subsequently Buck Creek, with a lower channel, kept working its head back towards Blue River, and finally, at a point one mile south of the Delaware line, captured it, conveying the water in a northwesterly direction to the White River. Blue River was left as a small creek which was entirely too small to keep the old river channel open. * * * A marshy condition began to develop, and a large amount of vegetation accumulated in the presence of water, which is seen today in the muck beds and the dark Wabash silt loam and Wabash loam soils that cover the surface."

The continuity of the Buck Creek-Blue River Valley is not due to stream piracy. The whole valley gives evidence of having been excavated by a large stream flowing southward. The only piracy is that of the channel.

In many moraines are shallow gaps which served as spillways for the water from the melting ice, but the floors of these gaps are far above the level of the bordering plains on the outer and inner sides of the morainic ridges. These four abandoned channels are unusual in that their floors have been excavated down to the level of the bordering plains. It seems that they served as glacial channels for a considerable time after the ice had retreated from the inner slope of the Mt. Summit Moraine.

The large terraces along East White River in Henry and lower counties and along the streams of the Whitewater system, as well as the extensive gravel plains in Wayne County are a measure of the enormous volumes of glacial floods that poured through these channels.

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[2] Phinney, Henry County and Portions of Randolph, Wayne, and Delaware: 15th Ann. Rept., Ind. Dept. Geology and Natural Hist.

[3] Taylor, A. E., 34th Ann. Rept., Ind. Dept. of Geology and Natural Resources, pp. 74, 75.

The land north of the Mt. Summit Moraine slopes to the west and the present drainage is in that direction. After the ice retreated north from this moraine in Randolph and Delaware counties, a dam, presumably a part of the ice sheet, still lay to the west and southwest. When this dam of ice melted away a lower outlet was opened up and these four valleys leading southward ceased to carry water from the melting ice.

After these valleys were abandoned by glacial waters, they received only the run off from short, transverse tributaries flowing from adjacent areas of the moraine. The small volume of water spreading out over the broad valley floors was unable to keep the channels open; and alluvial fans spreading out across the valleys soon converted the valley floors into a series of shallow basins in which thick beds of peat and muck accumulated. In time the postglacial streams to the south of the moraine worked back by headward erosion into these swampy areas, while tributaries of West White River, cutting back southward, came into them from the north.

Natural drainage was so poorly developed that it was necessary to dig large ditches to convert these swampy tracts into productive lands. Today these areas of rich black soil yield heavy crops of corn.

A striking feature of the broad belt of muck land which has been reclaimed by the dredging of Buck Creek and Blue River is the large amount of buried wood in it. In places farmers have dug up cords of wood closely resembling red cedar and used it for fuel. Large pieces may still be found just beneath the plow soil. Samples of this wood collected by State Forester Deam and the writer are in the State Museum at Indianapolis.

Southwest of Muncie is a valley which seems to have been excavated by a single stream, although at present two streams occupy it. In the northern part is Bell Creek which flows north into Buck Creek. In the southern part is Fall Creek. Between the two there is a portion of the old valley which is not cut by a stream channel. It is a broad swampy divide. The tributaries of these two streams (not well shown on the map), when studied in reference to the old valley, present some striking features. Since this old valley lies wholly on the northwest, or inner, side of the moraine it is merely mentioned here. It will be described in a future paper.

SOME CONTRASTS BETWEEN GEOGRAPHIC REGIONS IN INDIANA.

STEPHEN S. VISHER, Indiana University.

Indiana is strikingly uniform in many ways. There is comparatively little regional difference in rainfall, in temperature, or in altitude. Nevertheless, minor contrasts occur in Indiana in respect to many geographic conditions and have several significant effects.

Some of the contrasts which may be mentioned are those of climate, of types of soils, of altitude, of relief, of drainage conditions, of relations to waterways and railways, differences in farming practices, in chief crops grown, and in the conveniences and equipment in and about the farm home.

Temperature Contrasts. There is an average difference of about 5° F. between the southwestern corner of the state and the northern part, a difference of nearly 6° in summer and 8° in the maximum temperatures. The northeastern corner never has had an official temperature above 103° while the southern part has had a temperature of 111°. The sectional differences between the lowest temperatures ever recorded is somewhat less. The lowest is 33° below zero at Lafayette, while a temperature of 28° below has been officially recorded from Paoli and Jeffersonville. These differences in temperature are due chiefly to the differences in latitude, but are partly due to differences in altitude, the southwest corner of the state being within 350 feet of the sea level, while the northeast corner is above 1,000 feet.

The growing season, or the period without killing frost, in the southwest third of the state usually is nearly a month longer than in the northeastern corner. However, the frost-free season near Lake Michigan is, on the average, a week longer than somewhat farther south. The lake is comparatively warm in the autumn. Spring frosts occur near the lake as late as they do farther away but they do less damage to fruit trees because the cold winds from the lake and the cloudiness prevent early growth.

Contrasts in Rainfall. There are two chief types of sectional contrast in rainfall. The southern part of the state receives several inches more per year, but a larger fraction falls in the cooler six months than is the case in the northern part of the state. In the southern half of the state the average rainfall is 40 to 45 inches, while in the extreme northwestern corner of the state only 33 inches are received. In general, each month of the year receives about three inches of rain, but in the northern half of the state, about 55 per cent of the year's total falls during the warmer six months, while in the southern part of the state 50 per cent is received in that season. In the extreme northwest, 60 per cent of the precipitation comes in the warmer season, when it is most needed. The decrease in rainfall northward is related to the increased distance from the Gulf of Mexico, the one great source of rainfall for Indiana. The larger percentage in summer to the north is related to the fact that in winter, moisture carried northward by

"Proc. 38th Meeting, 1922 (1923)."

winds from the Gulf is dropped sooner than in summer because the continent is cold in winter compared to the ocean while it is comparatively warm in summer.

Snowfall. The part of the state near Lake Michigan receives three times as much snowfall as does the extreme southern part. (30 inches versus 10 inches.) Furthermore, it does not melt nearly so soon in the northern area, in fact it often remains on the ground for weeks, although it seldom lasts more than a few days in the extreme south end of the state.

Soil Contrasts. The soil shows many local differences, but the U.S. Bureau of Soils recognizes only five main soil regions in Indiana. The

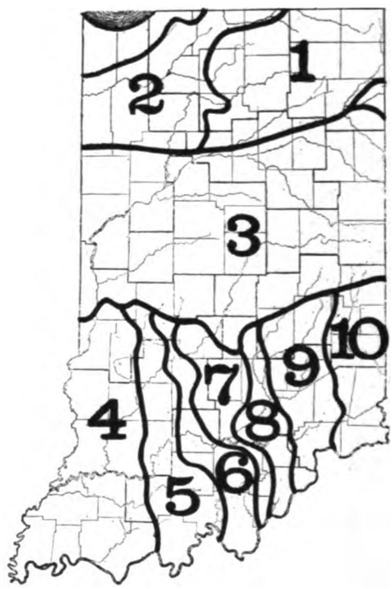

Fig. 1. Physiographic Regions of Indiana. 1=Morainal, 2=Kankakee, 3=North Central or Tipton Till Plain, 4=Wabash Lowland, 5=Crawford Upland, 6=Mitchell Plain, 7=Norman Upland, 8=Scottsburg Lowland, 9=Muscatatuck Slope, 10=Dearborn Upland. (After C. A. Malott).

great central section and much of the northern fourth are covered with a glacial clay loam. Considerable areas in the northwestern quarter are very sandy, while others have the famous brown soils of the northeastern Illinois corn-growing region. In southern Indiana, old glacial soils are found on the east and on the west, while soils derived from sandstones and those derived from limestones cover most of the middle portion of the southern third of the state.

Topographic Contrasts. In respect to relief or ruggedness, four main types may be recognized: (1) Prevailingly smooth to gently undulating, which is the characteristic condition in many counties in central Indiana. (2) Prevailingly gently rolling to rolling, which is true of

much of the southeastern quarter of the state, of a wide belt along the western side of southern Indiana, and also in many areas in central Indiana and northern Indiana. (3) Prevailingly rolling to hilly. This type is found in the lake region of the northeastern quarter, and is represented along the valleys of many streams, notably the Wabash northeast of Vigo County, and along the Whitewater. (4) the roughest part of the state is found along the Ohio River and in the unglaciated middle portion of southern Indiana.

The three-fold division of Indiana, which has often been made, that is Southern, Central and Northern, is largely based on characteristic differences in relief, but partly on differences in soil. Northern Indiana is the portion north of Benton County and the Wabash River. It contains many moderately rough areas, and considerable sandy soil, as well as muck land. Most of it, however, possesses a good glacial clay loam soil. Central, or north central Indiana is prevailingly level to gently rolling and possesses an excellent soil. Southern Indiana is the southern third of the state. These three great physiographic regions are shown in the accompanying map. (Fig. 1.)

Contrasts in Respect to Drainage. With respect to drainage conditions, most of southern Indiana was originally fairly well drained; most of central Indiana has been artificially drained, while large areas in northern Indiana are still undrained. The lakes and marshes of the state are nearly all in this northern section. More than half of southern Indiana was not glaciated while the remainder was glaciated much longer ago than was the case in central and northern Indiana.

Contrasts in Respect to Relation to Waterways. During the early settlement of the state, the relation to navigable streams was important. Then the southern margin, along the Ohio River, and the part along the lower Wabash were much better favored in transportation facilities than the rest of the state. The settlement of the part of the state nearest Lake Michigan was comparatively little affected by the lake because of the belt of sand dunes and marshes which separate the lake from the productive back country.

Later the canal built from Lake Erie to Evansville gave what was then considered a good means of transportation to a narrow strip. The spread of the population over the state from decade to decade reflects the importance of the waterways as highways. The population was fairly abundant along the Ohio, Wabash and Whitewater rivers when there were almost no settlers in large sections elsewhere in the state. Not until the railroad era commenced, about 1850, did the large areas of very sparse population disappear from the northern part of the state.

Regional Contrasts in Railroads. Today, in contrast, the northern two-thirds of the state is much better supplied with transportation facilities than is most of the southern third. There are two southern counties which have no railroads and several which have only a small mileage. Furthermore, a considerable share of the mileage in southern Indiana is of branch lines with inferior service. The chief reasons for this condition are, (1) the roughness of much of southern Indiana with the consequent difficulty in railroad building; (2) the lesser demand for trans-

portation in southern Indiana, which in turn is related to the greater poverty of the region and to its fewer industrial centers; (3) the fact that many more east-west trunk lines cross northern Indiana enroute to Chicago or St. Louis than cross southern Indiana.

Variations in Farms. The contrasts between different regions in the state are well illustrated by differences in the average value of the land. While according to the 1920 Census, the state average was $104 per acre, the Crawford Upland (figure 1, region 5) averaged only $26 per acre, and the Norman Upland only $31, but the wide, almost level north central region had an average of $158. The average values in the remaining regions outlined in figure 1 are as follows: 1—$102; 2—$91; 4—$71; 6—$32; 8—$74; 9—$43; 10—$51.

The variation in the per cent of land in farms is not so great, ranging from 82 per cent in the Norman Upland to 98 per cent in the Dearborn Upland. The wide central plain had 95 per cent of its land in farms. Other regions varied as follows: 1—92; 2—89; 4—88; 5—90; 6—89; 8—90; 9—93.

One might expect that the richer land of central Indiana would be divided into smaller farms than the poorer land in southern Indiana because a smaller acreage can support a family. But instead, the smallest farms, on the average, are found in the Norman Upland, of which Brown County is representative. There the average is 88 acres, in contrast with 114 acres in the north Central plain and 168 acres in the Kankakee region. The average size of farms in the remaining regions are as follows: 1—101; 4—94; 5—110; 6—101; 8—107; 9—99; 10—94.

Not only are the farms larger than the average in the smoother central part of the state, but a larger proportion of the land is in crops and a smaller proportion in pasture, wood lots and waste land. This is illustrated by the total land devoted to cereals per average square mile. The north central plain with 350 acres out of each average 640 acres has three times as large a share of the land in cereals as the Norman Upland with 117 acres. Other regions have intermediate acreages as follows: 1—259; 2—298; 4—282; 5—144; 6—164; 8—296; 9—172; 10—165.

The contrast in the total taxables per average square mile is great, and very important. The richest part of the state, the north central plain, has taxables assessed at $214,000 per square mile, on the average, whereas in the poorest region, the Crawford Upland, the valuation is $34,000, only about one seventh as much. No wonder that the schools and roads are better in the former region than in the latter! The valuation in other regions is as follows: 1—$112,000; 2—$88,000; 4—$122,000; 6—$40,000; 7—$61,000; 8—$103,000; 9—$50,000; 10—$60,000.

Accompanying these notable contrasts in the semi-permanent assets of the several regions, there is a conspicuous contrast in improvements and equipment on the farms. For example, one area, the Muscatatuck Slope, has six times as many silos in proportion to area as another area, the Norman Upland. Automobiles are least frequent, 2.3 per square mile, in the Crawford Upland, where roads are very poor

and the land is least valuable and the total taxables smallest. They are more than twice as abundant in the central plain and in the Dearborn Upland, both well developed regions. The automobiles are not only more numerous in the richer part of the state than in the poorer, but they average distinctly more costly per car. Tractors are six times as abundant in the north central plain as upon the Norman Upland. Indeed they are two or three times as abundant in the central and northern part of the state as in the southern, with its large areas of rough land. The distribution of auto trucks, however, is distinctly different from that of automobiles and tractors. Trucks are relatively most numerous in the Norman Upland, a region poorly supplied with railroads. They are least common in the Kankakee region with its many low and sandy areas and its many railroads converging towards Chicago. Milking machines are three times as numerous in the northeastern morainal section of the state as in the extreme southeastern or in the Scottsburg Lowland. Running water in barns is rarest in the regions of cheapest lands, the Norman Upland and Crawford Upland. It is commonest in the Scottsburg Lowland and in the morainal region with its extensive dairying.

Within the homes there is no less regional contrast than in the barns and in the value of the land. For example, according to figures given in the Indiana Yearbook, washing machines are six times as frequent on farms in the north central plain as in the Norman Upland and vacuum cleaners are four times as common in the plain as in the rougher sections. Furnaces are more than four times as common in the coolest northeastern section than in the poorer areas of southern Indiana. Electric devices in the farm home are 60 times as numerous in proportion to area in the Kankakee region than in the hilly and rather remote Crawford Upland. Kitchen sinks are three times as common in the north central plain and the morainal region as in the Norman and Crawford Uplands.

The reasons for the foregoing contrasts are largely due to the geographic differences mentioned in earlier pages. The effects of the differences in levelness, soil, climate and accessibility, are supplemented by differences in the education and ability of the people which are in turn related to differences in opportunities. Undoubtedly there is a tendency for many of the more alert young people to go from the less favored regions to the more favored. The discouragement afforded by the small, poorly equipped farms of the less favored areas is increased by the lower average yields per acre of important crops. For example, even along the relatively productive valley bottoms of the Norman and Crawford Uplands, the corn yield is not great enough to give those regions much more than half the average yield on the wide north central plain. Furthermore, so little land is suited to corn in the rougher parts of the state that the average farm had only about a third as many acres as the average farm in the central plain. In respect to wheat there is less contrast. According to the 1920 Census, the average yield in the Crawford Upland was 12 bushels in 1919, but 19 bushels in the Kankakee region. In the three upland regions of southern In-

diana the average farm contained less than 10 acres of wheat in contrast to about 20 acres in the Wabash and Scottsburg Lowlands.

Oats are relatively most important in the northwest part of the state (Kankakee region) where they occupy several times as large a percentage of the land as in the southern third of the state. They also yield far better in the northern than in the southern parts of the state. It may be due in part to the earlier coming of hot weather towards the south than towards the north. Oats, like wheat, stools more heavily and hence yields best where there is a considerable period of somewhat cool weather for it to grow in, before hot weather causes it to head out. Hay and forage are relatively most important in the rougher morainal section of the northeastern corner of the state and are least important in the poorest section of the state, the Crawford Upland of southern Indiana.

Contrast in the Value of Crops Grown. On the average, the poorer counties of southern Indiana each grew crops worth nearly $1,500,000 in 1919, while the better counties in the north central section grew crops worth about $8,000,000. The contrast between the poorest and the best counties in crop production thus is about as one is to eight, when comparative area is considered.

Sectional Contrasts in Manufacturing. In manufacturing there is much more contrast than in crops. Warren County, the county which does the least in manufacturing according to the last Census, produced only one eight-thousandth as much wealth by manufacturing as did Marion County, and only one eleven-thousandth as much as did Lake County. The value added by manufacturing in Warren County was only $16,000 in 1919 while that in Marion County was $136,000,000 and that of Lake County, $180,000,000. Four other counties did less than $100,000 worth of manufacturing in 1919. Strange to say, four of these five counties are in the northwestern part of the state near counties which do much manufacturing. Three of them do less manufacturing than Brown County which is the least active of the southern counties. However, when all of the southern counties are compared with the central and northern counties it is seen that southern Indiana is as backward in respect to manufacturing, on the average, as it is in so many other respects.

Fuller data concerning many of the foregoing points may be found in the author's Geography of Indiana, which is Part I of the Handbook of Indiana Geology, recently published by the State Department of Conservation, Indianapolis. The tables upon which these contrasts in agriculture and farm equipment are based are given in the Economic Geography of Indiana, soon to be published by D. Appleton & Company, where many other points mentioned above are presented more fully.

THE PALEOLITHIC STONE AGE IN INDIANA.

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When we say "Paleolithic" in Archeology the mind is almost sure to revert to the dim and mysterious past,—perhaps as far back as the so-called pale of human existence, and we would expect that any material facts connected with it would naturally be buried in an environment so indefinite and remote that one could scarcely grasp their meaning. Such instances have been found under conditions pointing back to very early times, even to the seemingly mythical Tertiary period, but in

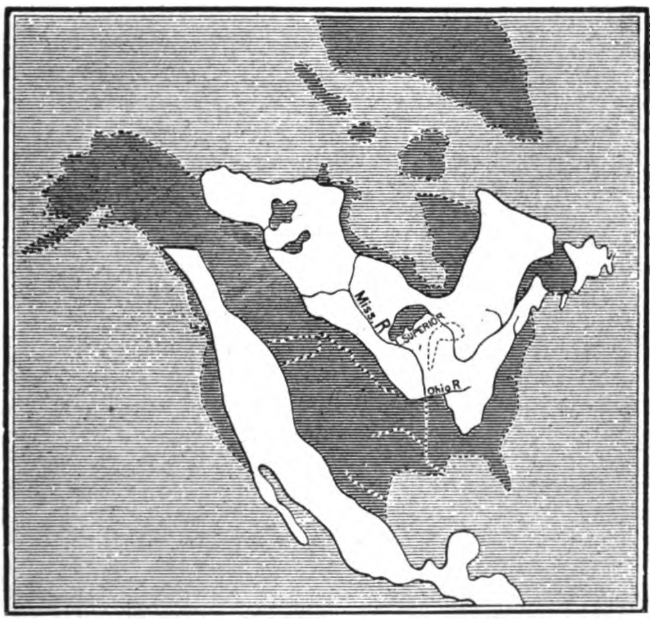

Fig. 1. Tertiary Sea of North America.

most cases the statistics pertaining to them have been so indefinite that they have been questioned.

"Races of Man," a very thorough and unprejudiced study of the human race, states that finders of artificially chipped flints, said to have become buried in the later Tertiary stratas, have few supporters at the present day. This can be more fully realized when we consider that the close of the Tertiary period saw the passing of the monster animals of the previous age and the coming of others more suited to a comparatively temperate climate. Large portions of the earth's crust became submerged and the ocean extended up the Mississippi Valley to the Ohio River section. California and Alaska were under water; the great Tertiary Sea spread over the western plains and up to the Arctic Ocean (fig. 1); and the coral builders were yet at work upon Florida.

Agassiz says: "The earth had already its seasons, its spring and summer, its autumn and winter, its seed-time and harvest, though neither sower nor reaper was there; the forests then, as now, dropped their thick carpet of leaves upon the ground in the autumn, and in many localities they remain where they originally fell, with a layer of soil between the successive layers of leaves—a leafy chronology, as it were, by which we read the passage of the years which divided these deposits from each other. Where the leaves have fallen singly on a clayey soil favorable for receiving such impressions, they have daguerreotyped themselves with the most wonderful accuracy; and the trees of the Tertiaries are as well known to us as are those of our own time."

Following this, from causes still imperfectly known, an accumulation of ice formed in the northern latitudes and glaciers extended into former tropical sections, and one glacier period succeeded another resulting in successive deposits also containing relics of former life and growths, and in this the Quaternary period, acknowledged evidence of the existence of man appears. "Races of Man," already quoted, states that: "In the quaternary beds the presence of human bones has beyond question been ascertained. The men of that period have handed down to us implements of a very rude type: fragments of flint of pointed form,—some were found along with the bones of animals which are now extinct; and objects of bone, horn, stag's horn and shell bear witness that Paleolithic man used tools or weapons made of other material than flint. A slow sinking of the land, which submerged beneath the ocean all the countries to the north and northeast of Europe, marks the end of the quaternary period; or from the archeological point of view, the 'earlier stone age' of the Paleolithic period. Of interglacial man, maker of those first flint implements exhumed from the lowest beds of the oldest quaternary alluvia, we have at the most, for the whole of Europe, but a dozen fragmentary skulls and a score of other bones genuinely quaternary. Of these the Neanderthal skull is typical of the early Paleolithic period, having an exceedingly low and retreating forehead, prominent brow ridges and probably a low stature." The same authority also states that: "The use of the bow was only known at a later period as arrow-heads of flint or bone have not been found in the early or Paleolithic period." And, further, that: "There is no people on earth which eats its food quite raw, without having subjected it to previous preparation, and no tribe exists, even at the bottom of the scale of civilization, which is not today acquainted with the use of fire, and as far back as we can go into prehistoric times we find material traces of the employment of fire, but real cooking, even of the simplest sort, is only possible with the existence of pottery, the manufacture of which must follow closely on the discovery of a method of obtaining fire, for no example is known of unbaked pottery."

To quote still further from the same source: "The Paleolithic period was succeeded by the present era in the geological sense of the word, which is characterized, from the archeological point of view, by another stage of civilization: that of the 'later stone age' or Neolithic period. In this latter period instead of the rude flint implements of the Paleolithic period, a variety of implements made their appearance."

Just how to differentiate between the Paleolithic and Neolithic cultures is a difficult problem. In the Paleolithic period man lived as an animal, procuring food from nature's supply which in certain climates is never exhausted, until his brain development suggested the first rude weapon and the first crude cooking utensil. A recent English publication,—"Man and His Past,"—gives a method quite unique in its way. The author, Mr. Crawford, says: "Man was the first animal to grow a limb outside of himself by making tools out of wood and stone. This was a great achievement, for with man the desire outstrips the performance. There is thus added a third factor, intermediate between man and his environment; so that the different kinds of interaction between the two are multiplied enormously. Man started his career in a comparatively defenseless state, with no limb or part of his body specialized as a weapon of defense or offence. That, perhaps, is why he alone picked up and used the flint around him. Moderate in all things, he lived a life of meditative aloofness in the forest, waiting for something to turn up. His patience was rewarded, for what turned up was not any kind of external goods but the key to all such—an intelligent mind.

"Now we are in a position to understand why it was that man, and man alone, has invented tools. The close connection between tools and brain becomes clear when we realize that primitive tools were the highest existing functions of brain made manifest. The power of intelligence grows with use, for it is quick to take a hint from its teacher, the tool. The tool is improved, fresh demands are made upon intelligence to use the new tool aright, and so the process is continued, each in turn helping the other. These tools may be regarded as art-products of a primitive kind, capable, therefore, of throwing light upon the nature of the men who made them, and so form the basis of all archeological work.

"The archeologist deals with the works of man in the past; it is through them that he is able to reconstruct a picture of the condition which obtained at any given period, and trace the evolution of culture."

The author, in connection with the above, teaches an object lesson by putting the matter in shape of a formula as follows:

(Animal) ————————————————————> (Object)
(Man) —————————— (Tool) ——————————> (Object)

Applying the above to the principal matter in hand,—that of drawing a line between Paleolithic and Neolithic stages of aboriginal life, we can take the first portion of Crawford's formula, where there is a direct contact of animals with their environment, as representing in a general way the Neolithic age of man up to and including the use of the elementary tools. And the second portion of the formula would represent the progression in the new sphere of life as found in the various stages of advancement in the semi-civilized, aboriginal culture, known as Neolithic.

In an article entitled "Lonely Australia: The Unique Continent," H. E. Gregory says that Paleolithic man, whose primitive tools are eagerly sought in caves and gravels of Europe, was alive in Tasmania within the memory of people now living, and Neolithic man is roaming

the deserts of Australia by hundreds, some armed with a stone hatchet, a club, a short spear with hardwood point, or a long spear with stone point. What such a life would be like at the close of the Paleolithic period can be inferred by an experience of Miller and Furness among the "Village Veddahs" of Ceylon, as reported by a University of Pennsylvania bulletin a few years ago. They say: "We followed the jungle path along the eastern shore of the reservoir, dammed for the purpose of irrigating the Singhalese rice fields; this path led close to the big pads of yellow lotus, and through thick undergrowths, until we came to a cleared space where there was the merest excuse for a hut, and beside it a man and woman squatted side by side and were cooking something in a blackened earthen pot. They had between them scarcely a yard of coarse cloth for clothing. Although they had never before seen white people, nevertheless neither of them showed the slightest astonishment or interest in our appearance; both glanced up for a second, and then continued silently shelling the seeds out of the lotus pods beside them, and stirring the simmering pot over the fire. The most impressive thing about them was their inhuman apathy and lack of interest, a peculiarity of the lowest type of man. The iris of the eye seems to merge indistinctly into the white, and the Singhalese say that the Veddahs have eyes like monkeys, because they are red, and they always look down or stare straight before them; this seems to be true as at such times their faces are utterly expressionless. Near them were five other shelters or huts, about eight feet square, with scant walls and dirt floors. The women and children were occupied in shelling the seeds out of the lotus pods and the chief when asked by our guide if there were special times during the day when they ate replied: They crack one nut and eat it, then crack another and eat it, until their supply is gone, and they sleep wherever they happen to be. Although they live near the lakes, abounding in fish, they are not fishermen, as far as we could learn."

This, then, is the childlike stage in man's development, and the question comes,—Was there such a period in the existence of man in America? If primitive man here was autochthonous then as a matter of course there was such a beginning. Agassiz and Dana have stated again and again that North America was the original home of man and the oldest area known. Prominent authorities have even suggested that the tide of emigration may have set the other way—from America to Asia.

Belief in the emigration plan of peopling the so-called new-world from a "dispersal center" in Asia still obtains. The Smithsonian Institution in their Handbook of American Indians says: "The fact that the American Indians have acquired such marked physical characteristics as to be regarded as a separate race of very considerable homogenity, from Alaska to Patagonia, is regarded as indicating a long and complete separation from their parental peoples." And it is further stated: "The term Paleolithic is applied to implements, usually of stone, belonging to the Paleolithic age as first defined in Europe and afterward identified in other countries. In America the Paleolithic, as chronologically distinct from the Neolithic age, is not established, and the more

primitive forms of implements, corresponding in general to the Paleolithic implements of Europe, can be properly referred to only as of Paleolithic type."

The latest from the Smithsonian Institution on this subject is by Holmes in "Aboriginal American Antiquities," as follows: "Old world cultures have come to be known as the Early Stone, the Late Stone and the Bronze ages. In America, classification of artifacts on the basis of culture steps is not attempted. Our aboriginal history as a whole lies entirely within the so-called age of stone. A discussion of the Stone Age is a comprehensive study of the whole subject matter of the aboriginal peoples and their culture." He says further: "The purpose of the archeologist is not merely to classify and describe antiquities but to make available an intimate knowledge of all the phenomena of aboriginal culture and apply it to the elucidation of the American race and to the history of the human race as a whole." But, in order perhaps to en-

Fig. 2. Clay figures taken from below an old lava flow near the Mexican volcano Xitli. Estimated age, 7,000 years.

courage classification of artifacts on a cultural basis, he also states: "It is the privilege of the archeologist to adopt such classification and take such points of view as he believes will best serve his particular purpose, the broader purpose being to place the whole body of the subject matter on record in the manner best suited to the needs of the anthropologist-historian, who in due course may expect to have at his command data sufficiently complete to enable him to give to the world a well-rounded story of the American race."

This permit comes very timely, for recently in Mexico some authentic geological and archeological explorations have, as they report, found data which calls for a "face about in archeology and history." It seems that a quarry had been opened up in an ancient flow of basaltic lava, and in the earth stratas below were found the remains of aboriginal life belonging to a very ancient culture. The age of the lava flow is established geologically at 5,000 years, and the indicated age of life previous to the eruption of the volcano Xitli is 2,000 years; making the

remains found at the lowest depth of the most primitive culture about 7,000 years old. These remains consist mostly of pottery, clay heads and figurines. The clay vessels are semi-globular, without much appearance of a neck, as though they were copies of holes in the ground, such as would be used in moulding the crude clay pots. The clay figures (fig. 2) of the lowest deposit are crude and grotesque beyond description.

The report states that they do not consider them to have been autochthonous, but that they arrived in Mexico probably by a northern route in the closing phases of the glacial epoch. Not considering them to have been native to the soil, and consequently not Paleolithic in the usual classification of peoples of that age of the world, they have selected a new appellation, calling them by the improvised name of To-achtopay-atlaca, meaning "our primitive people." This brings us back to a realization of a possible Paleolithic race in America, as ancient as any indicated in the Old World. Another interesting matter in the way of collecting archeological information is mentioned as follows: "Unfortunately although work has been carried on at the San Juan Teotihuacan pyramid for so long a period as 15 years, and a museum erected, it is reluctantly admitted that the material there is not arranged in scientific order, hardly any of the specimens having the place marked from which they were derived." This calls attention to the failure of noted specimens in the past to receive credit when they were apparently Paleolithic, but which were carelessly removed from their environment without data sufficiently accurate to permit a positive conclusion. A recent interesting find illustrates the case as follows: In a rock shelter, known locally as Jacob's Cavern, situated in the Ozark mountains in Missouri, there were found in April of last year (1921) a number of decorated bones, perforated as if used for a necklace. This cavern had previously furnished valuable specimens of aboriginal life when excavations were made for the Phillips Academy Museum some 20 years ago, and was a favorite resort for those who cared to dig for Indian relics. Mr. Taylor, the owner of the land and finder of the specimens in question, had from time to time dug further and further back, attempting to reach the extremity of the overhang. Stalagmites had formed in places and one of these had been shattered by a charge of dynamite without the owner's knowledge. In company with a friend Mr. Taylor happened to dig at the location of this stalagmite and unearthed nine specimens of perforated bone and shell. They were rudely ornamented with incised lines, one design having an outline suggesting the elephant (fig. 3) and two suggesting the deer. On exposure to the air the smaller bones soon crumbled and the larger ones were saved only by encasing in paraffin. Dr. Clark Wisler, of the American Museum, was asked to visit the premises, which he did in August, 1921. The results of his visit are given in a memorandum to Mr. Taylor as follows:

"The opportunity afforded me by your hospitality to examine the carved bone found by you and the privilege of exploring further in the cave, in the company of Mr. Randolph, Dr. Vernon C. Allison, and yourself, is greatly appreciated. Jacob's Cavern has long been known to us through the report of Peabody and Moorehead and has frequently been

cited as one of the possible type stations for early man in America. It is, therefore, of unusual interest to know that this site is by no means exhausted, but still rich in data. The question your find raises is whether the person who made the sketch on the bone which has been preserved saw a mastodon or mammoth. This cannot be answered positively, but the probabilities of the case can be estimated. In the first place, the work is of the primitive stamp and such as we might expect from the hand of an American native. It so happens that upon these bones at least three attempts were made to represent living forms, apparently by the same artist. Two of these forms have the distinctive lines of elk and deer, while the lines of the third characterize elephant kind. This favors the interpretation that an elephant, mastodon, or mammoth was intended. At once the objection will be raised that the bone is recent. Though the mastodon and the mammoth are characteristic of Pleistocene time, it is not known when they became extinct; for all that is known to the contrary, these great mammals may have

Fig. 3. Carved bone from Jacob's Cavern. Note carving representing a mastodon type of mammal.

held out to within three thousand years ago. Thus, the artist could have seen one of these animals and still have lived under modern conditions. No one in authority seems now prepared to deny that man was in America three thousand years ago. In other words, there is nothing zoölogical that makes your interpretation improbable. We must, therefore, turn to the cavern itself. It appears that this bone was found in the present surface of the cave, but approximately five feet of deposit were taken out by Moorehead in 1903; hence this bone is older than anything found by him. When we recall that both Peabody and Moorehead were impressed with the great age of what they removed, the evidence is again favorable to your interpretation. Also, there are still in the cavern almost five feet of deposit, in the main clay, through which you were so kind as to sink a shaft in my presence. This excavation indicated the presence of man's handiwork in all parts of this deposit, one piece of worked stone being found at the bottom of the shaft, lying flat upon the original stone floor of the cavern. One must conclude, therefore, that there are remains in the cavern that are of

greater age than the bone in question. In general, then, I regard this site as one of the most important yet discovered and one demanding further investigation. Regardless of what may ultimately prove to be the significance of this carved bone, you have made a discovery of great promise. I assure you of my appreciation of your confidence, in extending an invitation to make further excavations in this deposit and its surroundings. So, pending the examination of the site, as indicated above, no further comments seem necessary. The writer will do everything he can to further this investigation to the end that the complete story of Jacob's Cavern may be revealed. It is to be hoped that at last we are on the trail of early man in America."

Smithsonian bulletins have this to say on the subject in general: "Caves and rock shelters representing various periods and offering dwelling places to the tribes that have come and gone, may reasonably be expected to contain traces of the peoples of all periods of occupancy. Vast areas of limestone rocks of varying age occur in which are countless caves, the great caverns of Kentucky, Indiana, Virginia and Missouri being well known examples. It is observed that in general these caverns have existed for a long period, extending back well beyond the time when man is assumed to have appeared on the continent; but the deposits forming their floors, with few exceptions, have not been fully examined and up to the present time have furnished no very tangible evidence of the presence of man."

These meager results may possibly be accounted for by the fact that rare antiques have been and are expected as a reward for digging, delving and exploring. What an explorer should hope to find, if he is skilled, is something which will enable him to date and explain the site he is excavating, or the period to which it belongs. Regarded in that way, the intrinsic value and beauty of the objects found is irrelevant. This idea of archeological research applies forcibly to the work of determining the beginnings of aboriginal man in America, for the proofs are rare and Nature has buried them deep. Mexico has its volcanic lava flows which have preserved the records in stone; and other sections have lake dwellings with shell heaps in which traces of early man lie buried; but here in mid-continent the mounds and caverns must be looked to for ancient and unwritten information. Ohio has obtained a most enviable history in its mounds and earth embankments, but this is mainly in the way of remarkable achievements by the later cultures of that prehistoric Indian race. In no section probably is there a better field for research than in Indiana, for there is hardly a county in southern Indiana but what can show caves or rock shelters, and in some they are very numerous. It would not necessarily be a large cave that would be most desirable for habitation, and the Indiana Historical Commission in its work of developing a State Archeological and Historical Survey will probably be able to locate those which show signs of having been in such use.

Scattered over the length and breadth of the land in almost all directions are the innumerable conical mounds which vary in size and apparent use, some being of a sepulchral nature while others bear traces

of religious rites in which fire was made use of, and others bearing no trace of their real use. In the sepulchral mounds the objects buried with their various owners indicate the predominant traits of character of that people, being mostly the stone weapons for self-defense and the slate gorgets or charms of supposedly supernatural power. Of the weapons, most are of a flint nature, breaking with a splintery fracture and chipping to a sharp edge with a conchoidal fracture. The very first weapon, that of a spear head (fig. 4), is taken to be the first stone implement fashioned by man, and was done in a crude way,—simply a pointed stone of a shape which could be fastened to a shaft to form a

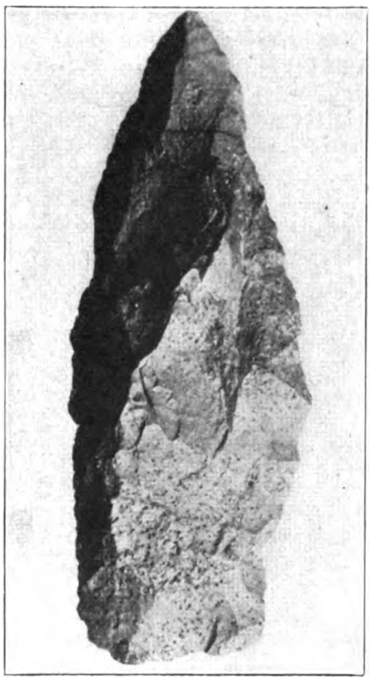

Fig. 4. Rude flint spearhead, Paleolithic type. Original.

spear. This marked his entry into the realm of investigation and art craft, and is taken to mark the latest phase of Paleolithic life. Following this came the multitude of artifacts marking the stages in Neolithic culture.

The spear or lance came early to hold a prominent place on ceremonial occasions, being suited for prominent display in processions and dances. Flint from which the spearhead was formed appears most abundantly in Ohio, Illinois and Indiana, and large aboriginal quarries were worked in the two former states. Kaolin, a clay desirable for pottery, also abounds in this territory, so that two things most conducive to growth in the earliest period were present, and the multitude

of mounds and earthworks are evidence of the presence of a third dominant feature, religious ceremony.

A large proportion of the conical mounds show no implements interred and no traces of burial, but the latter can be accounted for if an age of construction which could easily run into the thousands of years is conceded, in which time every vestige of bone even would have disappeared. The immense earth embankments at Fort Ancient in Ohio are conceded to belong to the earliest stage of aboriginal life which left visible traces of this kind behind them. Indiana shares with Ohio the landmarks so laboriously erected by this unknown race, for they lie on the outskirts of the territory marked by earth embankments of circular, square, elliptical and irregular outline which extends west along the southerly side of the great lakes into Indiana. Smithsonian bulletins say of them: "The Mound-builders seem to have skirted the southern border of Lake Erie and spread themselves, in diminished numbers, along the territory south of Lake Ontario, and penetrated into the state of New York as far as Onondaga where some slight vestiges of their work were found. These seem to have been their limits to the north-east. They extended in the same manner westward into Iowa and Nebraska, but no record is had of their occurrence above the great lakes. They are distinguished for their regularity, most of them being circular or square in form, and are found isolated and also in groups. They are mostly of a diameter of 250 to 300 feet and almost invariably have the ditch interior to the wall, and always have a single gateway. The enclosure was sacred and set apart as 'tabooed' or sacred ground."

In Wisconsin a wonderful profusion of earth embankments prevail and are radically different from those forming the chain along the territory south of the great lakes. They are mainly of two general outlines,—straight, linear embankments and those of animal and bird outlines, all of which are interspersed with conical mounds. The peculiar features of linear mounds are that while on an average of two or three feet in height, they begin with an increased height at one end and taper in width and height to almost a point at the other end; and, further, that in some cases they begin on a level plateau with the high portion and extend down the adjoining slope decreasing in size almost to a point. This latter feature is also found in some cases of irregularly shaped mounds and effigy outlines. The mounds are seldom over eight feet in height and the earth embankments are frequently only about two feet in height and often merely a trace. While the circular earth embankments of the great lakes region, as a whole, indicate an almost exclusive ceremonial use, those in Wisconsin go farther by representing living forms and probably were endowed with mythical life, and we are again reminded of the fact that the Indian was an "animist", to whom every animal and object in nature contained a spirit to be propitiated or appeased. Another feature peculiar to Wisconsin is the matter of so-called "Garden-beds." They are located in valleys and cover acres of ground in the form of ridges three to five feet apart, with a furrow between. They are parallel and are mostly straight but in some cases are broken by sections having parallel curved ridges or irregular

outlines similar to a turtle back. As a whole they resemble very closely the designs on pottery, particularly those reported from the Cahokia group of mounds in Illinois, across the Mississippi river from St. Louis. There may have been a relationship between these people who lived in the same river valley and made use of similar designs. The emblems on the pottery are understood to have had a mythical meaning, and these ridges are apparently of a ceremonial nature.

Referring again to the earth embankments in Indiana which form a part of the chain of earthworks stretching along the south side of the great lakes, the group at Anderson was described in the Geological report of Indiana for the year of 1878; and again in 1892 by F. A. Walker of Anderson, who read a paper at the annual meeting of the Indiana Academy of Science of that year, which was published in the Academy Proceedings, but without a copy of the photographs which

Fig. 5. Portion of circular embankment in Mounds Park at Anderson, Indiana. Photograph made by Mr. F. A. Walker in 1892. Original.

had been made. He had a survey made and described the group as consisting of seven structures of circular and oblong outline, the largest one being 360 feet in diameter, 1,131 feet in circumference, covering two and one-third acres. The maximum height of embankment is given as over 9 feet and accompanied by an interior ditch of about 12 feet maximum depth, and having an opening or gateway of 30 feet between ends of embankment. Mr. Walker took great pains to secure photographs of this embankment (fig. 5), and we take pleasure, after a thirty years interval, of seeing them again presented.

Another embankment, second in importance in Indiana, is at Strawtown in Hamilton county, northeast of Noblesville. We say second in importance, for while it is a single embankment instead of one of a group, yet at the same time is one of the noted exceptions in the way of construction, being one of the few having the ditch outside of the

embankment. It was reported in the Geological report of Indiana for the year of 1875 as being 280 feet interior diameter, the ditch being 30 feet in width and about 9 feet deep.

A third embankment is of a rectangular shape and located at Winchester in Randolph county, a portion of which was formerly within the county fair grounds. In the Geological Report of Indiana for the year 1878 it was reported as containing about 31 acres, the interior area being about one fourth mile in length and over a thousand feet in width. The embankment was 6 to 8 feet high with a gateway at each end, one of which had an elaborate entrance in the form of a crescent. It is remarkable as to outline and for having no ditch accompanying the embankment; also in having two gateways, inasmuch as Smithsonian descriptions say these single earthworks invariably have but one gateway.

Indiana is most fortunate in having these three groups or instances of aboriginal earthworks which may prove to be primeval. They are specially interesting as they represent three different types of construction and commemorate a remarkable race of primitive times and one with a personality which American history will be proud to record.

Of the use to which these earthworks were put, Smithsonian conclusions are as follows:

"On the whole, the American Indians incline strongly towards all forms of religious excitement. Their festivals and games were accompanied by religious rites, some being confined to groups and others participated in by whole tribes. Specially prepared lodges or grounds were tabooed, into which none but the initiated could enter, and which were indicated in such a manner that the public might not mistake it. The ceremonies formed intrinsic features and may be regarded as phases of culture, their special character depending on the state of culture of the people by which they were performed; hence there are at least as many kinds of ceremonies as there are phases of culture in North America."

As to segregating the phases of culture and working out a sequence, which has probably been awaiting the completion of sufficient exploration, it would seem practicable to draw the same line in the stone age that is done in Europe, viz. the early or primitive stage as separate from the later or perfected stage. As flint may be taken as emblematic of the early period, being the material so easily fractured into the form of a spearhead, so may we select the stone of hard and tough texture, such an granite, syenite, diorite, basalt, etc., as typifying the late period in the stone age. This tough, grained rock was subject to abrasive treatment in the way of hammering, pecking and rubbing to give a desired outline and cutting edge. The first implement in this line to be worked out has been considered to be the hatchet shaped implement known as the "celt" (fig. 6) which appears in about the same form in the stone age of European countries. It required long and patient work to give it the required outline, and then the cutting edge was formed by a rubbing or polishing process, and this polishing in some cases was applied to the entire surface of the implement.

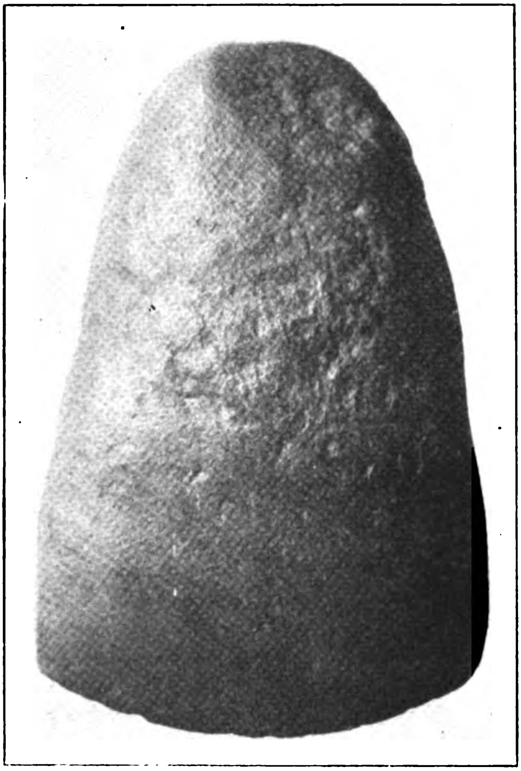

Fig. 6. Celt of smoothed stone, Neolithic type. Original.

The line between the two stages of aboriginal life in the stone age, known as the early and late, is well drawn by the Encyclopedia Americana, 1920 edition, as follows:

"The art of polishing stone implements was introduced near the beginning of the Neolithic period. It is on this basis,—the absence of polished stone implements in the deposits of the Old Stone Age and their presence in those of the young Stone age,—that the names Paleolithic and Neolithic are given."

RECENT ARCHEOLOGICAL DISCOVERIES IN JEFFERSON COUNTY, INDIANA.

GLENN CULBERTSON, Hanover College.

During the year 1922, some further investigations were made into the archeology of Jefferson County. One result of this work was the discovery of an additional mound, located along the bank of the Ohio River, approximately one mile above the mouth of Indian Kentucky creek in Milton Township, near the middle of section seven, on the Coleman farm. This mound is on what is locally known as the second bottom, or first terrace, and had been so undercut by the waves of the Ohio River during recent floods, that at least half of it had fallen away. The remnant indicated that the original mound had been 75 or 80 feet in length and 40 or 50 feet in width.

Near the middle of the mound lengthwise, and at a depth of some two and a half feet below the present surface, the writer found exposed where the bank had fallen away, a complete human skeleton lying at full length. The bones were much decayed, being, in that respect, very similar to those taken from the Lawson mound, a few miles away, some 20 years ago. Several parts of the skull, one clavicle, one humerous, a few vertebrae, the head of the left femur, and two teeth, incisors, were obtained in a fair state of preservation. Measurements of the remains indicated the height of the person to have been somewhat over six feet. The right humerus measured exactly 14½ inches in length, and one of the finger bones also indicated a person of rather unusual height. The bones of this skeleton are at present in the geological museum of Hanover College.

At the same level as the skeleton, which was that of the base of the mound, were found many fragments of Ordovician limestone partially burned and badly decomposed, a few fragments of river mussel shells, and several fragments of very hard river boulders and pebbles of glacial origin. Since it is very difficult to break these boulders even with a heavy hammer, the probabilities are that these had been broken by heating to a red heat and then plunging into a vessel of cold water in cooking or other operations. No implements of stone were found closely associated with the skeleton, but many arrow heads, tomahawks, pestles, polished fleshers, and other such articles have been, and are still being picked up from the surrounding bottom lands. Judging from the number of implements found, and fragments of chert and of flint to be seen in the vicinity for several hundred yards from the mound, this site was probably that of a village. Flint such as may be picked up at this place is not found in any geological formation within many miles.

Another recent discovery of archeological interest in Jefferson County was that of a cache or deposit of flint implements. This cache was found early in 1922, on the farm of Hiram Foster in Graham Township, in the northeast quarter of Section 15, Township 4 North, and Range 9 East, some 300 yards from the old Hartwell mill site on Big creek. The immediate location of the deposit was a clay point

"Proc. 38th Meeting, 1922 (1923)."

from which one or more feet of soil had been removed by erosion. There is no evidence of the deposit having been made in a mound or in connection with an unusual structure. Ninety implements were taken from this cache, all of which, except one, were in perfect condition. A few of the implements had been exposed by erosion, the others were obtained from a space not more than a foot or so across. Some 70 of these implements were in the possession of Mr. Foster, and others had been sold by the party who had removed them from the cache. Mr. Foster kindly donated six typical specimens to the geological museum of Hanover College. The implements of this deposit are composed of pure flint, and are remarkably uniform in shape. They are ovate in outline, varying in length from five to ten inches, in breadth from three to six inches and in thickness from three-eighths to five-eighths inch. All were finished entirely around the edges very much as an ordinary arrow or lance head. They were made of flint and are therefore quite dark in color. Circular and oval markings on the greater number of them show that they were made from flint concretions. The source of these concretions was not local, but probably from the Mississippian limestone of Harrison and Crawford Counties.

The purpose for which these implements were manufactured is largely conjectural. Some consider them to have been made for spades or hoes. If it were not for their evidently finished condition, they might be considered as material in course of preparation for arrow or lance heads. Neither theory as to their use is satisfactory.

The writer wishes to suggest that, in making the proposed archeological surveys of the different counties in Indiana, the implements found in each county, be placed in county, state, or institutional collections. In Jefferson County almost every farm house contains a few implements, but there is no one very large collection. If all specimens from a county could be placed in one group, properly labeled, and the name of the owner, and the locality in which the collection was made, attached, county collections of great interest and value could be accumulated.

ARCHEOLOGY IN POSEY AND VANDERBURGH COUNTIES.

A. J. BIGNEY, Evansville College.

Posey County is located in the extreme southwestern corner of Indiana, bounded on the west by the Wabash River and on the South by the Ohio River. The county has broad, low bottoms along these rivers, rising gently toward the interior, with numerous hills breaking the general level of the county. More than twenty lakes dot its surface, Hovey Lake, which is circular and about one mile in diameter, being the largest.

Vanderburgh County lies directly east of Posey County and is much smaller. Low bottoms several miles wide border the Ohio River, and the country rises gently into the hills and higher land in the center and northern part of the county. West of Evansville these hills approach the Ohio River.

The natural location of this section of the state seemed to have made it attractive to the earliest known inhabitants, the Mound Builders, later the Indians, and finally the white man. The New Harmony movement had its rise, development and failure in the western part of this territory, at the town of New Harmony. Even Audubon and Say found this an interesting and fruitful locality to study birds and insects.

In Posey County there are four mounds west of Mt. Vernon, not far from the river, but on high ground. In the eastern part of Vanderburgh County there are five mounds of considerable size. The only mound away from the river is found about twelve miles north of the Ohio. It has been largely explored and most of it has disappeared. These mounds have been more or less completely explored and the specimens distributed to many parts of the United States, the Smithsonian Institution having secured many of them. In the Museum at New Harmony large numbers of these relics have been placed and are now exhibited to the public. Last year a Museum Society was organized and incorporated in Evansville to receive a large collection from Sebastian Henrich. This collection, which is entirely local and made by Mr. Henrich, has been arranged and placed on exhibition in rooms in the Willard Library in Evansville. It consists of about 2,000 arrow points of great variety, and many of them the finest I have seen, a large number of drills, besides some good pieces of pottery, many splendid pipes, hundreds of celts, axes and copper specimens.

Another similar collection was made by C. F. Artes of Evansville. After his death it was sold for $7,500 and removed from the city. A third collection, now consisting of about 5,000 specimens, half of which are arrow points, is owned by Mr. Otto Laval, who lives five miles east of the city of Evansville. His collection of drills is the best that has been made in this section. The mortars or grinding stones are of rare patterns, one being eighteen inches in diameter. One has an oval concavity and a pestle ground to fit it. His copper specimens, one of which

is a helmet, are superior. The collection of pipes is also very good, as well as the minerals, axes, celts, and a large variety of pottery.

In addition to these large collections, many smaller ones have been made in an incidental way. New specimens are being found from time to time. Last year a very peculiar one was found ten miles east of Evansville near the mouth of Green River by a negro while digging a hole in which to bury a dead animal. This specimen (fig. 1) which is

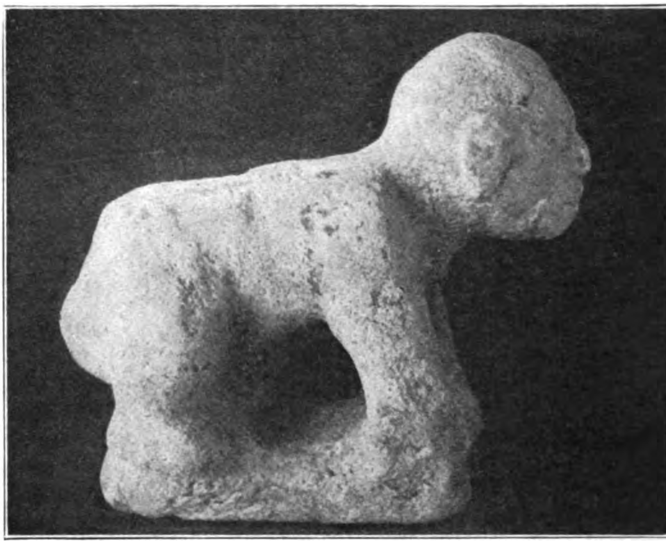

Fig. 1. Indian pipe taken from a mound near Evansville, Indiana. About one-half natural size.

recognized by the Smithsonian authorities as a pipe, is six inches high and seven inches long, and is made of light gray sandstone. It represents a man on all fours with head raised, and has two conical holes in it, one on the back and one in the rear—the two holes connecting. One hole served as the bowl and the other for the attachment of the stem. Having been found in the alluvial deposit, it indicates that it had been washed there. In the locality where this pipe was found are the five mounds of Vanderburgh County referred to above, and it seems highly probable that it came from one of these, either directly or from some house where it had been kept as a relic after having been taken from a mound.

Not only are works of man found in Posey and Vanderburgh counties, but also the remains of some of the ancient animals as well. A few weeks ago a part of the tooth of a mastodon was found in the river at West Franklin, 12 miles below Evansville. Near the same place, not long since, a thigh bone was found which weighed 55 pounds.

GONIOBASIS LIVESCENS MENKE, A PLEISTOCENE SHELL IN FURNESSVILLE BLOWOUT, DUNES OF PORTER COUNTY.

Marcus Ward Lyon, Jr., South Bend.

On the floor of the Furnessville Blowout[1] is a comparatively large bed of small, white, and somewhat weather-worn univalve shells. Closely associated with them are flat, rounded, water-worn small stones like those that are so frequently found at the low water edge of the lake.

Fig. 1. *Goniobasis livescens* on the floor of Furnessville Blowout. The small white objects in the foreground are the shells. In the distance are some low fore dunes just beyond which is Lake Michigan.

In 1921 a small handful of these shells was picked up and sent to Dr. Paul Bartsch of the United States National Museum. They were identified as *Goniobasis livescens* Menke of Pleistocene Age. Dr. Bartsch suggested that the place where they are found possibly represents an old shore line. With reference to the present shore line and level of Lake Michigan this open bed of shells is found about 150 yards south of the present shore and about 15 feet above the present level of the lake. (Fig. 1.) It lies immediately back of a line of low fore dunes.

[1] On the shore of Lake Michigan, opposite Furnessville station of the Chicago, Lake Shore and South Bend Railway.

"Proc. 38th Meeting, 1922 (1923)."

In the absence of figures of actual surveys the impression is that the floor of the Furnessville Blowout is probably lower than the floors of other blowouts in the region and also that it is approximately the same height as the low ground between the dunes and the tracks of the Chicago, Lake Shore and South Bend Railway. Although I have been in many of the blowouts in this region, between Michigan City and Oak Hill, the one designated as Furnessville is the only one in which I have found these shells.

No opinion is ventured as to the significance of these shells at the place indicated.

A REVIEW OF THE PRESENT KNOWLEDGE OF FOSSIL SCORPIONS WITH THE DESCRIPTION OF A NEW SPECIES FROM THE POTTSVILLE FORMATION OF CLAY COUNTY, INDIANA.[1]

By JOHN IRWIN MOORE, Owensville.

The following paper is a condensed review of the literature on fossil scorpions with the description of a new species from the Pottsville formation of Clay County, Indiana.

Interest in Fossil Scorpions. Wide interest in fossil scorpions was first aroused by the discovery of a specimen in the Silurian rocks of Sweden which was first made known to the Swedish Academy of Sciences, on November 12, 1884. The fact that this "apparently carried the history of air-breathing or land animals much further back in geological time than had hitherto been known"[2] was enough in itself to attract wide interest. A published statement of the Swedish find first appeared in Comptes Rendu of the French Academy, Dec. 1, 1884. This was closely followed by an announcement of the discovery of a specimen in the Silurian rocks of Scotland, published in the Glasgow Herald, Dec. 19, 1884. Almost a year later (Oct. 10, 1885) a similar find was announced from the Water-Lime beds of New York (Silurian). This almost simultaneous discovery of rare and peculiar fossils caused accounts of them to be published in many scientific and popular journals.

Their Bearing on Geological History. At present fossil remains of scorpions have been described from the Silurian and Carboniferous, and from amber deposits of Oligocene Age. According to Fritsch[3] the order Scorpionida attained its acme during the Carboniferous and subsequently declined.

As stated above the Silurian scorpions constitute the earliest suggestion of land or air-breathing animals, but Whitfield, concludes that they could not have been air-breathers but were wholly aquatic and that their descendants acquired the terrestrial habit in subsequent generations. Pocock has suggested that the supposed mesosomatic "sternites" of Palaeaphonus are really broadly laminate gill-bearing appendages, as they have been shown to be in Eurypterus[4]. Similar appendages occur in the Carboniferous Genus Eobuthus, and it is inferred that respiratory lamellae lay beneath them as they do in Limilus[5]. Many writers have expressed the belief in the origin of the scorpions from the eurypterids and this has been used in the development of a theory for

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[1] To Professor Stuart Weller I wish to express my thanks for many valuable suggestions and for his encouragement in attempting the study and description of the specimen. From my brother Prentiss D. Moore I received much assistance in the preparation of the photographs. Greatest thanks are due Arch Addington of Indiana University, who saved the specimen for description.

[2] R. P. Whitfield—On a Fossil Scorpion from the Silurian Rocks of North America. Bull. Amer. Mus. Nat. Hist., Vol. I.

[3] Zittel—Text Book of Paleontology.

[4] Clarke and Ruedeman—New York Geol. Sur.

[5] Zittel—Text Book of Paleontology, p. 788.

the origin of the vertebrates which is discussed at length by Patten[6] and Gaskell[7].

Present State of the Knowledge on Fossil Scorpions. Petrunkevitch[8] also thinks the Water-Lime specimen must have been a marine form, and here it might be well to add a few words on the conclusions reached in his study of the phylogenetic development of the scorpions. He says: "That the different classes of arthropods must have developed not from one ancestor but at different times and from different species of chaetopodous worms;" that the scorpions no farther back than Carboniferous times were not equipped with internal lung books and in the structure of these parts they do not resemble the eurypterids as was suggested by Pocock; that eurypterids have in some respects closer relations with limuloids than with scorpions; that the Bertie water-lime, which contains the eurypterid having the closest resemblance to scorpions, also contains the oldest true American scorpion; and finally, that the Xiphosura, Eurypterida and scorpions developed independently and that the great similarity is due to convergence as Thorell suggested. Some have suggested that the different sub-classes "must have been differentiated even in Pre-Cambric times[9]." The well preserved specimens from the Oligocene indicate that the scorpions then had practically the same habits as they possess today. Schuchert[10], in his discussion of the Silurian forms, after summing up the evidence, concludes that they were semi-aquatic, living along the shore, above the Strandline, feeding on small crustaceans and other small invertebrates.

Fossil Carboniferous Scorpions. The Carboniferous scorpions have been extensively treated, by Fritsch in continental Europe, Pocock in England and Petrunkevitch in North America. Petrunkevitch in describing the 16 available specimens from North America placed them in ten species, six genera and four families. The likeness between some of the Carboniferous forms and the recent forms is very striking.

Present State of Classification of the Order. Each one of the workers in this field has arrived at a different conclusion as to the classification of the order; so I will here give a brief summary of the existing state of the classification.

The Classification of Karsch. Karsch[11] divided the order into four genera, *Eoscorpius*, *Microlabis*, *Cyclaphthalmus* and *Mazonia*. In his classification *Eoscorpius* Meek and Worthen contained: *Anglicus*, Woodward and *Carbonarius*, Meek and Worthen. *Microlabis* Corda, contained the species *sternbergii* Corda. *Cyclophthalmus* Corda, contained the species *senior* Corda. *Mazonia* Meek and Worthen, contained the species *woodiana* Meek and Worthen.

Work of Scudder and His Classification. Scudder[12] in his work two years later recognized only three genera placing all of them in the

[6] Patten—The Evolution of the Vertebrates and Their Kin.
[7] Gaskell—The Origin of the Vertebrates.
[8] Petrunkevitch—Trans. of Conn. Acad. of Arts and Sciences, Vol. 18.
[9] Petrunkevitch—Trans. of Conn. Acad. of Arts and Sciences, Vol. 18.
[10] Schuchert Textbook of Geology, Vol. II.
[11] Karsch, F. E.—Zeitschr. deutsch. Geol. Ges. (1882), pp. 556-561.
[12] Scudder, S. H.—Proc. Amer. Acad. Arts and Sciences, Vol. XX, 1884, pp. 15-22.

family Eoscorpionidae. He considered the genus *Microlabis* as synonymous with *Cyclophthalmus*. In the genus *Eoscorpius* Meek and Worthen, he placed *carbonarius* Meek and Worthen, *anglicus* Woodward, *euglyptus*, *glaber*, *inflatus* and *tuberculatus* Peach. The genus *Cyclophthalmus* contained *sternbergii* and *senior* Corda.

Hasse's Redivision of the Order. Hasse[13] redivided the order Scorpiones with respect to the true scorpions, into the sub-order Anthracoscorpii, family Eoscorpionidae and sub-families Eoscorpionini and Cyclophthalmi.

Fritsch in Continental Europe. Under the order Scorpiones, Fritsch[14] recognized the sub-order Dionychopades and family Anthracoscorpii, which he divided in seven genera. To the four genera,—*Eoscorpius* Meek and Worthen, *Microlabis* Corda, *Cyclophthalmus* Corda, and *Mazonia* Meek and Worthen, recognized by Karsch, he adds three new genera and two new species from material mainly undescribed. These new genera and species are as follows: *Isobuthus kralupensis* (Thorell and Lindstrom), *Eobuthus rakovnicensis* and *Feistmantelia ornata.*

Pocock in England. In his monograph on the English forms, Pocock[15] made some radical revisions of the classification. He first divided the order Scorpiones (other than Silurian) into two divisions, the Lobosterni, and the Orthosterni. The Lobosterni contained those forms having bilobed, posteriorly-laminate sternal plates on the opisthosoma and skeletal plates on each side of the genital operculum. In the division Lobosterni, he placed the genus *Eobuthus* of Fritsch to which he assigns a single species *holti*, a very fragmentary specimen, from the Shipley Clay pits. Pocock also thought *Isobuthus* of Fritsch might be assigned to the same group. The division *Orthosterni* contains the genera *Archaeoctonus*, *Cyclophthalmus* and *Anthracoscorpio.* To *Archaecctonus* Pocock, he assigned *Eoscorpius glaber* Peach, and *E. tuberculatus* Peach. In the genus *Cyclopthalmus* Corda, he placed the species *Eoscorpius euglyptus* Peach. In the genus *Anthracoscorpio* he placed *Eoscorpius sparthensis* (Baldwin and Sutcliffe) and added two new species, *dunlapi* and *buthiformis.*

Late Revision of the American Species by Petrunkevitch. In America Petrunkevitch[16] has revised the entire Class Arachnida. In his work on the scorpions he was able to bring together all the then known specimens for re-examination. He divided the order Scorpiones into two sub-orders, the Apoxypoda containing the Silurian forms and the Dionychopoda containing the Carboniferous forms. In the sub-order Dionychopoda he recognized four families, 12 genera and 23 species, of which six genera with nine species are restricted to Europe, and five genera with six species are restricted to America. The genus *Eoscorpius*, regarded by Pocock as unsound, is accepted by Petrunkevitch. To it he

[13] Hasse, E.—Zeitsch. deutsch. Geol. Ges. 1890, pp. 629-657.

[14] Fritsch, A.- Palaeozoische Arachniden, 1904, Prague pp. 5-80.

[15] Pocock, R. I. Monograph of the Carboniferous Arachnida of Great Britain, Pal. Soc.

[16] Petrunkevitch, A. Monograph of the Carboniferous Arachnida of North America, Trans. of Conn. Acad. of Arts and Sciences, Vol. 18.

assigns eight species, four occurring in Europe and four in America. No species are found to be common to both continents. From these facts Petrunkevitch drew the two following conclusions: (1) "that the Carboniferous arachnological fauna of North America is distinct from that of Europe and developed along somewhat different lines," and (2) "that both faunas have more similarity with recent faunas of tropical countries, than with such of the same locality."[17] The following outline brings out Petrunkevitch's classification very clearly:

Order *Scorpiones*.

"Head completely fused with the thorax. Abdomen twelve-jointed, the last five somites forming the so-called cauda or post abdomen, considerably narrower than the anterior seven. Telson with a poison gland and sting. Chelicerae three jointed, chelate. Pedipalpi six-jointed, chelate, powerful. Coxae of first and second pair of legs with maxillary lobes. Abdominal tergites and sternites heavily chitinized connected laterally with each other by means of a soft chitinous cuticle capable of considerable distension. Post abdominal segments without pleural membranes, their sternites and tergites completely fused in each segment. First sternite represented by the genital opercula, second sternite by the basal joint of the comb. Four pairs of stigmata leading to lung-books in third to sixth sternites, one pair to each sternite. Anus without operculum at the end of the twelfth abdominal segment, ventral to the poison gland. Two middle eyes and two to five pairs of side eyes on cephalothorax, some recent species completely blind. All recent scorpions are viviparous."

Sub-order—*Apoxydopa* (Silurian).
- Tarsi terminating in a sharp point, without claws.
- Family *Palaeophonidae* (T. & L. 1884).
  - Genus *Palaeophonus* (3 species, all European.)
  - Genus *Proscorpius* (1 species, American.)

Sub-order—*Dionychopoda*.
- Scorpions with two claws at the end of each tarsus (includes Pocock's Lobosterni and Opisthosoma). The families of this sub-order are based on the structure of the coxae and not upon the shape of the abdominal sternites.
- Family *Isobuthidae*. Coxae of the fourth pair of legs abutting against the genital opercula.
  - Genus *Isobuthus* (1 species, European).
  - Genus *Eobuthus* (2 species, European).
  - Genus *Palaeabuthus* (1 species, American).
- Family *Cyclophthalmidae*. Normal arrangement of coxae, sternum pear-shaped.
  - Genus *Cyclophthalmus* Corda, 1835 (2 species, European).
  - Genus *Palaeomachus* Pocock, 1911 (2 species, European).
  - Genus *Archaeoctonus* Pocock, 1911 (1 species, European).

[17] Petrunkevitch, A. Monograph of the Terrestrial Paleozoic Arach. of North America, Trans. Conn. Acad. of Arts and Sci., Vol. 18, p. 28.

Family *Cyclophthalmidae*
Genus *Eoctonus Petrunkevitch* (1 species, American).
Family *Eoscorpionidae.*
Normal arrangement of coxae, pentagonal sternum.
Genus *Eoscorpius* Meek and Wcrthen, 1868, (8 species, 4 American and 4 European).
Genus *Trigonoscorpio* (1 species, American).
Genus *Palaeopisthacanthus* (2 species, American).
Genus *Microlabis* Corda, 1839 (1 species, European).
Family *Mazonidae.*
Middle eyes close to anterior edge of cephalothorax. Structure of pedipalpi and sternum unknown.
Genus *Mazonia* Meek and Wcrthen, 1868 (1 species, American).

The classification proposed by Petrunkevitch has the advantage that it is based on characters ascertainable even from fossil specimens, although derived from the comparative anatomy of recent forms. This classification will be followed as closely as possible in the description of the specimen in hand.

Comparison of Fossil Scorpions to Modern Forms. In the comparison of most fossil organisms with living forms usually only the broader features can be considered, for the finer generic and specific characters upon which modern forms are differentiated are commonly lacking to a greater or less degree. This condition is met with among the Paleozoic scorpions. The general morphology of scorpions has changed but little since Silurian times, the greatest modifications being in the structrue of the legs and feet and the much debated breathing apparatus. It has been suggested by some authors, after a comparison of the shape of the bodies of some fossil scorpions, that the viviparous habit was acquired before Carboniferous times. These characters may have followed as a result of the change from an aquatic to a terrestrial habitat.

Brief Notes on the Morphology of Modern Forms.—Only the external characters with which this paper is concerned, will be considered here.

Scorpions are animals with a segmented chitinous exterior skeleton, the anterior segments of which are fused to form the cephalothorax. The praeabdomen is composed of seven broad, thick, mcvable segments which surround the principal viscera. A prolonged extension of the praeabdomen, consisting of five segments, is known as the postabdomen. The last segment of the postabdomen is armed with a stout curved spine which bears at its extremity the opening of two ducts leading from a pair of glands lying in the twelfth abdominal segment and secreting a poisonous fluid.

The first pair of appendages are called the chilicirae and are situated in front of the mouth. These appendages are chelate. The next pair of appendages are the strongest appendages and are provided with chelae. Their chief service is in grasping and bringing food to the mouth. The coxae of the second, third and fourth pairs of appendages are situated about the mouth and serve as jaws. Behind the pedipalps

are four more pairs of appendages, the six-jointed walking legs. The abdomen is also supplied with modified appendages. The first segment of the praeabdomen probably bears the genital opening. The second abdominal segment bears a pair of appendages called the pectines, or so-called combs whose function is not very well understood. The ventral surfaces of the third to sixth abdominal segments, inclusive, bears each a pair of stigmata, the exterior openings to the lung-books which are the respiratory apparatus.

The eyes are situated on the dorsal surface of the cephalothorax and vary from two to six in number. One pair of eyes are larger and are situated near the median line. The others which are smaller are lateral. Some of the modern forms are blind.

Scorpions are viviparous, the genital orifice occupying the same position in both sexes.[16]

The Indiana Specimen. The specimen here under discussion was secured by Arch R. Addington in Clay County, Indiana, while serving in the capacity of assistant to the State Geologist. Mr. Addington recognized the importance of the fossil and later presented it to P. D. Moore, who in turn placed it in my hands for study and description.

Condition of the Specimen. The specimen was collected in a clay pit which had been opened in a shale member of the Pottsville formation. The specimen lying with its dorsal surface exposed is not an impression only in the soft shale, but it preserves the exoskeleton in the form of a thin, brown, chitinous film. The preservation of the specimen is excellent except that most of the terminal segments of the walking legs are missing and the fourth and fifth joints of the postabdomen are badly crushed. The left pedipalp is crushed back on the tip joints of the first left walking leg. The preservation of the remainder of the specimen will be considered as each part is taken up for description.

Geological Position. The specimen was found in a shale member of the Pottsville formation, in the basal portion of the Carboniferous series, of Clay County, Indiana. The Pottsville formation in Indiana consists of a series of sandstones and shales interspersed with coal seams. One thin lime-stone is present overlying the lower Minshall coal located in the upper or Brazil portion of the series. The Pottsville outcrop in Indiana has a northwest southeast trend upon the western side of the Kankakee branch of the Cincinnati arch, extending from Benton County on the northwest to Perry County on the Ohio River, Clay County being near the middle of the area. The general dip of the strata is to the southwest passing beneath the younger Pennsylvanian formations.

Zoölogical Relations of the Species. The preliminary examination of the specimen and the comparison with the descriptions and illustrations of the other American forms showed that it was a member of a genus previously unknown in America. Its characters at once suggested its affinity was with the European genus *Eobuthus* and continued study

[16] For further discussion on the morphology consult J. Playfair McMurrich—Textbook of Invertebrate Morphology.

has confirmed its reference to this genus, which becomes the second genus of the Paleozoic scorpions to have representatives on the two continents.

Eobuthus pottsvillensis n. sp. (Plate II. figs. 1, 2, 3, and 4.)

This species is represented by a single specimen, the ventral surface of which is exposed. Since all the other known examples of this genus also preserve the ventral side, satisfactory comparisons can be made.

The measurements of the specimen are as follows:

Total length—37.6 mm.
Length of tail—16.7 mm.
Length of first joint of tail—3.1 mm.
Length of second joint of tail—3.8 mm.
Width of next to last segment of abdomen—8.8 mm.
Length of chela—9.4 mm.

The structure of the cephalothorax is indeterminable due to the condition of fossilization.

The shape of the praeabdomen is an elongate oval. The sternum is clearly oval or sub-oval in outline. In shape it is closely similar to the British and Bohemian specimens except that the sternum of the latter specimens seems larger in proportion. The bilobed shape of the third, fourth and fifth sternal plates is very striking, and they seem to overlap in shingle fashion. No traces of stigmata can be observed even when examined under the high power binocular. The sixth praeabdominal segment curves in a convex line and joins the postabdomen, whose first segment is about one-half the width of this last segment.

The first two segments of the postabdomen are well preserved and show the keel structure in a remarkable degree. The third joint of this division of the body is partly destroyed, but the general size and shape of the first three segments are about the same. The fourth and fifth joints are badly crushed and lost and their outlines can barely be determined. The telson or poison sting is well preserved and lies deeper in the matrix and to the left of the main trend of the tail, this being the first specimen of the genus which has this part of the body preserved.

The appendages are as follows:

The outline only of the chelicerae is determinable. The right one stands out in advance much farther than the left. Their chelate structure can only be inferred.

The right pedipalp is fairly well preserved, the left one being crushed back on the tips of the first left walking legs. In comparison with other specimens these appendages are moderate in size only. The chela of the right pedipalp is preserved in an edgewise condition which gives it a very slender appearance. The position and length of the movable finger cannot be determined.

Only the coxae of the first pair of walking legs are preserved and the position of these seems to be normal. More of the second pair of walking legs is preserved than of any of the others. The right second walking leg is only preserved to the third joint which is

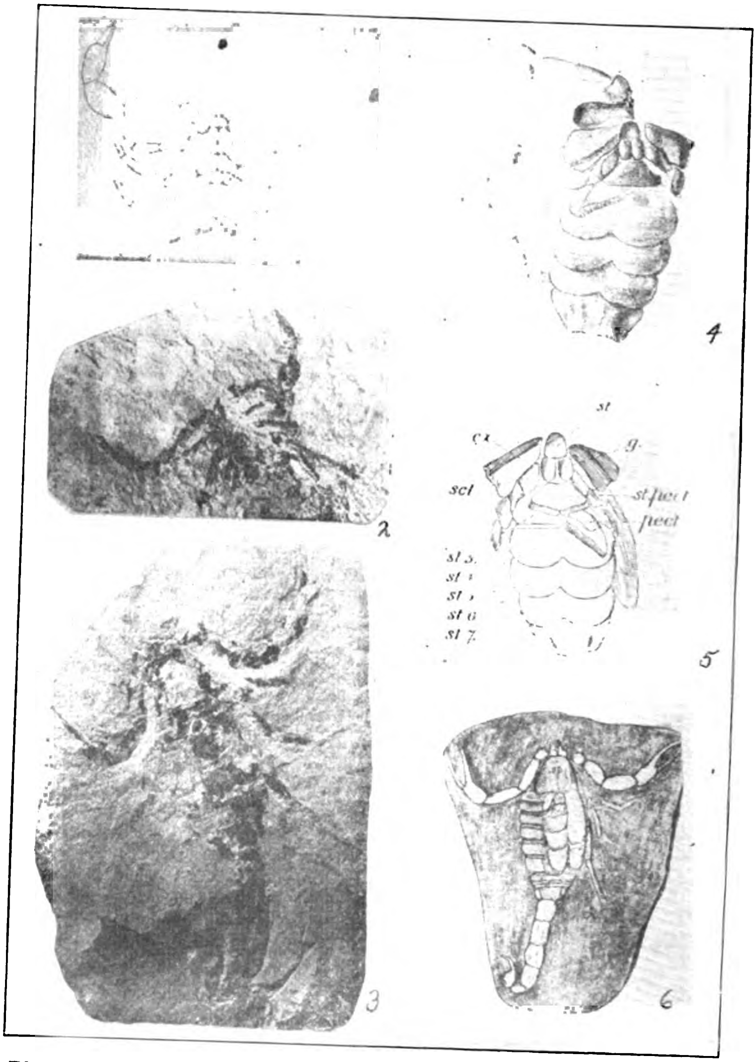
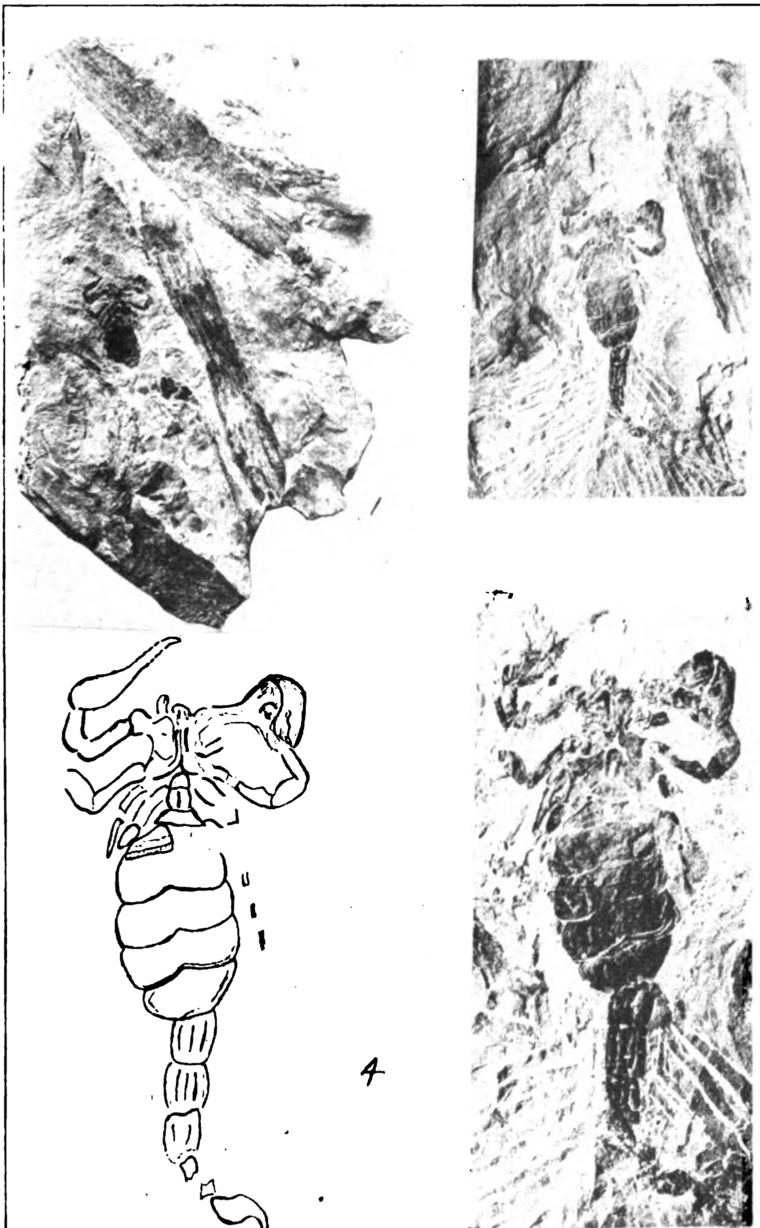


Plate I. Figs. 1 and 2, *Eobuthus rakovnicensis*, the figure 1 being a restoration by Fritsch from the genotype. (Fig. 1: 1, chelicerae; 2, coxae of pedipalps; c, coxae of second walking legs; b. basal plate of pectines.) Figs. 3 and 6, *Anthracoscorpio sparthensis*. Fig. 4, *Eobuthus holti*, found in the coal measures at Sparth, near Rochdale, England. Fig. 5, line drawing of figure 4 (after Pocock); *cx.* coxae of third leg, *g.* genital operculum, *pect.* one of the pectines, *scl.* schlerites abutting genital operculum, *st. 3* to *st. 7* third to seventh somites of opisthosoma.



Plates II. ***Eobuthus pottsvillensis*** **n. sp. 1, condition when discovered; 2, as it appeared when the postabdomen had been uncovered (slightly less than natural size); 3, enlargement of 2; 4, line drawing to bring out structure.**

club shape in outline, probably due to flattening in fossilization. The tip joints of the left second walking leg seem to be preserved but they are in contact with the crushed left pedipalp and their outlines are difficult to distinguish. Only the first two joints of the third and fourth pairs of walking legs are preserved. The coxae of the third pair seem to be situated a little more anterior than the coxae in *E. holti* although all the coxae resemble *E. holti* more than *E. rakovnicensis*. The basal joints of the fourth pair of legs abut against the genital operculum. These are the skeletal plates referred to by Pocock, about whose function he was in doubt. The Indiana specimen clearly shows that these belong to the fourth walking legs.

One pectine is very well preserved and the other one very faintly. Its structure as well as its plate of attachment is essentially similar to that in *E. holti*. The plate of attachment is roughly pentagonal in outline.

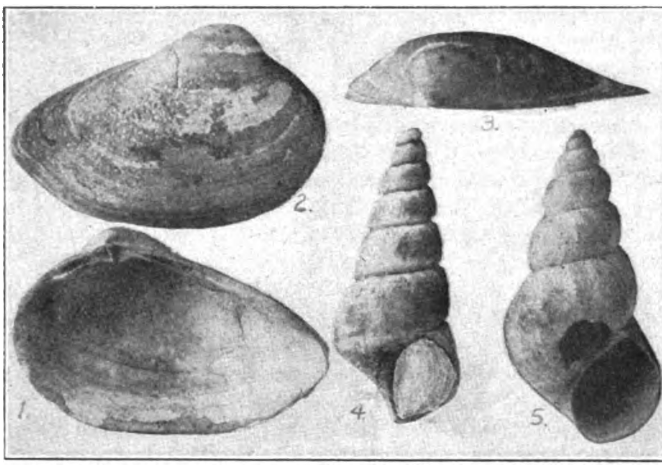
No trace of the stigmata has been detected.

General Observations and Comparisons. This specimen is better preserved than either of the other two specimens assigned to the genus. It exhibits all features except the dorsal surface and the extreme tips of the walking legs. Its closest relation is with *E. holti* (Pl. I, figs. 4 and 5) rather than with the genotype, but it differs from the single known fragmentary specimen *E. holti* in the shape of the praeabdomen and the position of the coxae, with also the probable difference in the ratio of the size of the sternum. It differs from *E. rakovnicencis* (Pl. I, figs. 1 and 2), the genotype, in the shape and length of the pedipalpi, and in the shape of the coxae and pectine. The absence of stigmata and the structure of the sternites suggests that these forms were not air-breathers but possessed respiratory organs similar to Limulus.

THREE NEW BRACKISH-WATER PLIOCENE MOLLUSCA FROM LOUISIANA.

Ernest Rice Smith, DePauw University.

In a paper published in the Proceedings of the United States National Museum, Vol. 46, pp. 225-237, W. H. Dall listed a considerable brackish-water Pliocene fauna, including many new species from the Atlantic and Gulf Coastal Plains of the United States. Outcrops of this horizon are found at intervals from the Satilla River, Georgia, to Newton County, Texas. One locality, which yielded him a very considerable fauna, was the Frank Muse Place, six or eight miles southwest of Alexandria, Louisiana.



Figs. 1, 2, and 3, *Mulinia harrisi* n. sp.; fig. 4, *Paludestrina dalli* n. sp.; fig. 5, *P. olssoni* n. sp.

In 1916, Professor G. D. Harris of Cornell University, made a small collection in a well, about thirty feet below the surface, on the Hunting Club grounds ten miles southwest of Alexandria. This material, washed and sorted, furnished twenty-one molluscan species, seven being Pelecypods and fourteen Gasteropods. The elements, believed to be new, consist of the three species here describd as new and an imperfectly preserved Gasteropod, kindly examined by Mr. Dall who determined it as probably a *Melaraphe* Mühlfeldt. I wish to express my appreciation to Professor Harris for the opportunity to study this material and to Mr. Dall for his examination of the material believed by me to be undescribed.

Mulinia harrisi n. sp. Figs. 1, 2, 3.

This species resembles *Mulinia sapotilla* Dall and was confused with that species, because of inadequate material, in the paper mentioned above. It may be separated from that species by its deeper and better

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defined sinus, by its somewhat more slender form vertically and by its slightly greater globosity. Mr. Dall confirmed my opinion of the distinctness of this form by comparision with the original of his *M. sapotilla*, replying as follows: "The *Mulinia* which you sent agrees exactly with the specimen from the Pliocene of the Satilla River, Georgia, which I identified with my *M. sapotilla* from the Shell Creek Pliocene of Florida. After a comparison with yours, the differences seem constant." The same species probably occurred in the material which Dall had from the Frank Muse Place, but he did not compare my specimen with that material. The illustration, in the reference referred to above, seems to me to be *M. harrisi*, without question.

The type is a right valve in the Harris Collection, Department of Geology, Cornell University, Locality 134.

Length 15.8 mm.; height, 10.4 mm.; length in front of median line through the beak, 5 mm.: length behind the median line, 10.8 mm.; thickness, 3.4 mm.

Paludestrina dalli n. sp. Fig. 4.

Six smooth whorls; no umbilicus nor umbilical chink; whorls slightly flattened, angularly shouldered just below the suture; mouth slightly extended anteriorly in a somewhat flattened lip, departing from oval shape due to this extension, the flattening and the slight sutural shoulder; apex small, blunt. The mouth of the type is not entire, so it is impossible to say whether the peristome is thickened or not.

Length, 5 mm.; width, 2.1 mm.

The type is in the Harris Collection, Cornell University.

Paludestrina olssoni n. sp. Fig. 5.

Six smooth, evenly tapering, somewhat convex, unshouldered whorls; very small umbilical chink; apex acute; peristome unthicknened, oval.

Length, 4.35 mm.; width, 2.13 mm.

This species is named for my friend, Mr. Axel Olsson.

The type is in the Harris Collection, Cornell University.

QUALITATIVE ANALYSIS—TIN GROUP.

RALPH W. HUFFERD, DePauw University.

Numerous complaints from students that their results in the analysis of the tin division were not clear-cut caused the writer to investigate the matter. Two difficulties were found with the method generally employed. The first was in separating the tin group from the copper group, where care in avoiding solution of the latter led to incomplete solution of the former. The second was in separating tin and antimony from arsenic where appreciable amounts of arsenic sulphide dissolved to cause trouble later on.

Since it is generally necessary to remove traces of copper and mercury from the tin group precipitate, it was decided to make the treatment with polysulphide so severe that this procedure would become the rule. This would insure complete separation of the two divisions.

A somewhat similar decision was made in the case of the second part of the problem. It was decided to heat the reprecipitated tin group sulphides with 12N HCl at the temperature of boiling water since it is a simple matter to remove the arsenic sulphide which dissolves.

In order to avoid the difficulty which students have with the use of test-lead in reducing tin, aluminium was substituted for lead with good results.

The method finally adopted is as follows:

Method. Wet the sulphides on the filter with ammonia in an evaporating dish. Add about 15cc. polysulphide and set over a beaker of boiling water for five minutes. During the heating, the dish should be covered with a watch-glass. The contents should be stirred occasionally. Filter and treat the residue a second time with ammonia and polysulphide. Filter into the original filtrate. The residue contains all but a trace of the copper group.

Make the filtrate just acidic with dilute HCl and filter. Transfer the precipitate and paper to a dish and heat over boiling water with about 15cc. 15N ammonia for three to five minutes, adding more ammonia from time to time to replace that which boils off. This treatment dissolves the tin group sulphides. Filter, and wash the residue with warm ammonia. The residue may be added to the copper group precipitate. Acidify the filtrate with 6N HCl, being careful not to add a great excess and filter.

Transfer the paper and precipitate to a large test-tube and add 10cc. 12N HCl. Set the tube in a beaker of boiling water for ten minutes. Cool, filter, and wash the precipitate on the filter with 5cc. cold 6N HCl. Confirm arsenic in the residue.

Add 20cc. water to the filtrate. Unless this dilution causes the precipitation of orange antimony sulphide, pass in hydrogen sulphide until it starts to precipitate or to saturation if it does not appear. If antimony has precipitated, warm until it redissolves and filter. If it is absent, filter. This treatment removes all arsenic.

Boil the filtrate down to about 20cc. and transfer it to a large test-

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tube. Add .1-.2g. 30-mesh aluminium. Warm the solution and shake it while the metal is going into solution so as to insure contact of the metal with all parts of the solution. Continue to heat until all gas-evolution has ceased so as to avoid carrying over tin with the precipitated antimony. Let the black antimony settle to the bottom of the tube and decant the liquid through a filter into a tube containing some mercuric chloride solution. A white precipitate, which may turn gray, proves the presence of tin.

Wash the black precipitate in the tube with hot 12N HCl and with water to remove traces of tin. This may be done by decantation. Cover with 3cc. HCl, add a few drops of nitric and boil to destroy the aqua regia. Dilute to about 20cc. and pass in hydrogen sulphide. An orange precipitate proves the presence of antimony.

The writer wishes to thank his student, Mr. Merrell Fenske, for the aid he has given in working out this problem.

QUALITATIVE ANALYSIS—IRON GROUP.

RALPH W. HUFFERD, DePauw University.

Careful examination of the results obtained by several classes in Qualitative Analysis has led the writer to the belief that no other group causes so much trouble or consumes so much of the students' time as does the Iron Group. Further study has brought out the fact that the most commonly missed members of this group are cobalt and zinc. The difficulty with the first of these seems to be due to faulty application of the potassium cobaltinitrite test, and with the second, to failure to extract zinc from the group precipitate and the reluctance of the average student to seek for it in the second division precipitate.

Investigation of the various tests for nickel led the writer to attempt a modification of the old Morrel-Vogel test. The results in this direction were quite satisfactory and pointed to the possibility of greatly simplifying the scheme of analysis of the whole division.

Attention was then directed toward the zinc problem. If zinc could be satisfactorily separated from the second division, the necessity for the very annoying and time-consuming second precipitation and filtration of cobalt and nickel sulphides would be avoided. This notwithstanding contrary belief on the part of certain authors, was found to be quite satisfactorily accomplished by using a large excess of sodium hydroxide in separating the two divisions. (It must be noted that this procedure may increase the quantity of silicic acid in solution, though in no case has there been evidence of nickel being present in the zinc sulphide precipitate.) There is no desire on the part of the writer to deny that small quantities of zinc may be carried over in the second group precipitate but he does hold that except in very extraordinary cases it is unnecessary to look for it as the greater part of it will show up in the proper place.

Several other slight deviations from the more commonly accepted methods will be noticed in a study of the revised method which follows. They are all in the direction of speeding up the process without lessening its accuracy.

METHOD OF ANALYSIS.

Dissolve the group precipitate of sulphides and hydroxides (adding the filter if difficult to separate from the precipitate) in warm 6N HCl, adding a few drops of HNO_3 if necessary (if cobalt or nickel is present). If the filter was added, remove the fibers by sucking the solution through a Hirsch funnel. Wet the pulp remaining in the funnel with water and draw the water into the filtrate. Except for particles of sulphur the pulp will be white after this treatment.

Boil the filtrate for a minute and then add 30 per cent NaOH solution until a precipitate forms and persists after shaking or, if no precipitate appears, until solution is strongly alkaline. If there is a precipitate, add a further excess of 5-10cc. NaOH. Cool and add 1-3g. Na_2O_2 a little at a time with stirring. Add about half a gram of solid Na_2CO_3 and boil for a minute or two. Dilute with two volumes of hot water and boil for three minutes. Filter hot through an ordinary filter, the writer using a suction filtration by preference. Wash the precipitate on the filter with hot water, collecting the washings with the filtrate. The filtrate is treated as directed in Noyes' "Qualitative Analysis" for the separation of the first division metals.

The paper carrying the precipitate is spread out in a dish and covered with 15cc. boiling 6N HNO_3. This treatment dissolves or loosens the precipitate from the paper so that it can be transferred to a beaker. The paper is washed with another portion of hot acid and the solution added to the other. The solution is evaporated to 10cc. and 10cc. 16N HNO_3 added. The boiling solution or suspension, as the case may be, is removed from the flame and about a gram of $KClO_3$ is added with stirring. This produces complete precipitation of the manganese as the oxide unless there is a very large quantity of it present. Twenty cc. hot water is added, the solution or suspension boiled and filtered hot through an ordinary filter. Oxalates, if present, slow up the precipitation of the manganese and sometimes necessitate a second evaporation and addition of chlorate.

The filtrate contains iron, cobalt, and nickel, and fourth group ions if phosphates, oxalates, etc. are present. When these interfering ions are absent, add quickly with stirring a volume of 15N NH_4OH 5cc. in excess of the volume of HNO_3 present. If iron is present it will appear as the brown hydroxide. Quickly heat almost to boiling and filter hot. Wash the precipitate on the filter with 2-5cc. NH_4OH, collecting it with the original filtrate. Confirm iron in the precipitate.

In a tall 150cc. beaker boil off the ammonia from the filtrate until its odor is weak but noticeable. Pour off about one-fifth of the solution and test for nickel by adding a few drops of dimethylglyoxime solution. If nickel is present, a red precipitate will form at once. It is never necessary to correct for hydrogen ion concentration in this test if the above directions are closely followed.

Evaporate the remainder of the solution to a syrupy consistency and pour it into a test tube. Cool, and add enough water to bring most of the solid into solution. The reaction at this point is acidic. Add 3cc. 10 per cent KCNS solution and then 2.5cc. amyl alcohol-ether

solution (1 vol.: 3 vol.). For convenience in the laboratory these solutions may be kept in bottles fitted with bulb tubes so marked that the correct volumes may be withdrawn and added to the solution to be tested. Shake gently. If cobalt is present the upper layer will have a distinct blue-green color. If the color is not distinct carefully add a few drops of 12N HCl to the ether layer. Presence of cobalt produces the blue color. A colorless or straw-colored layer indicates its absence. This test can be applied in most cases to the original solution if iron is absent.

When oxalates or phosphates are present, they may be removed in the usual way by precipitating the iron, cobalt, and nickel as the sulphides after removing the manganese and treating the precipitate.

Results.

The following mixtures gave good, clear-cut tests for all of the metals shown. The numbers represent milligrams of the atom named.

	Zn	Cr	Mn	Fe	Co	Ni	Al
1.	—	—	9	9	1.8	9	—
2.	—	—	3.6	3.6	3.6	18	—
3.	—	—	1.3	13.3	.7	13.3	—
4.	—	—	2	100	1	100	—
5.	5	—	—	250	—	—	—
6.	5	—	250	—	—	—	—
7.	5	—	250	250	—	—	—
8.	5	—	500	500	—	—	—
9.	5	—	500	500	2	3	—
11.	5	8.5	500	500	2	3	—
12.	.5	—	1	—	.5	5	—
13.	.5	17	18	20	10	5	—
14.	2	—	500	500	1	10	—
15.	10	—	100	100	2	100	100

Summary.

A simplified scheme for the analysis of the Iron Group has been worked out which takes less time and appears to give more consistent results than the methods generally used.

The troublesome reprecipitation of cobalt and nickel as the sulphides and the careful adjustment of the reaction of the solution for the dimethylglyoxime test for nickel have been eliminated.

The Morrel-Vogel test for cobalt has been improved.

A table showing the wide range of application of the scheme described is given.

The writer acknowledges indebtedness to his students, Donald Hoffman and Howard Dick for their aid with the experimental work, and to Professor J. H. Reedy of the University of Illinois and Professor J. F. G. Hicks of the University of Nevada for testing out the method with their students.

THE EFFECT OF NON-METALLIC IMPURITIES ON CEMENTITE DISTRIBUTION IN STEEL.

G. B. WILSON, Purdue University.

It is a well known fact that non-metallic inclusions in iron and steel exert injurious and very undesirable effects upon the metal. Since it has been impossible entirely to eliminate their presence they have been the subject of much investigation and discussion.

Their weakening effect upon the steel is much more pronounced than can be explained by assuming that they are essentially the same in their effect as would be produced by cavities of the same size. Inclusions which may occupy a very small proportion of the cross sectional area of a given piece of steel very often prove fatal, whereas the total effective area of the metal lying between the inclusions would seem to be sufficient to withstand the strain. Their importance to the manufacturer and to the user of steel then is vastly greater than their size might at first indicate.

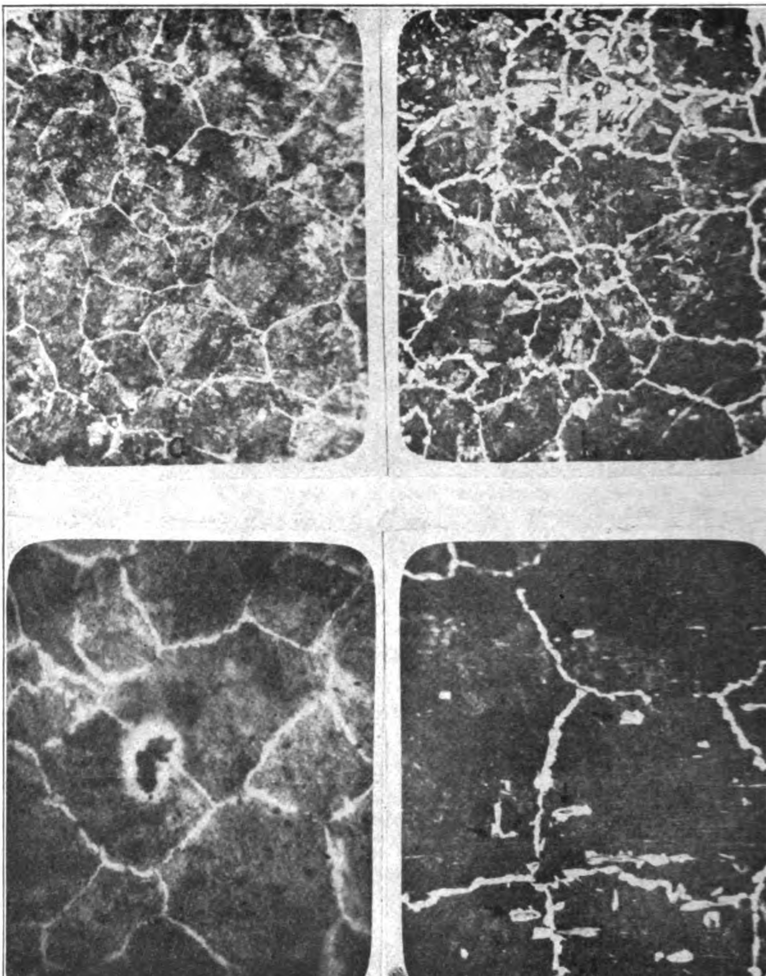
When pure hyper-eutectoid steel (steel containing more than 0.87 per cent carbon and generally called high carbon steel) is heated above its critical range it is composed of austenite. The upper limit of this range varies from 725° to 1125°C as the carbon content varies from 0.87 to 1.7 per cent. Austenite is essentially solid iron with carbon in the form of iron carbide (Fe_3C) dissolved in it. Iron carbide as a constituent of steel is called cementite. If the steel is slowly cooled nothing happens except that the austenite grains increase in size until the first recalescent point Ar^{cm} is reached. At this pcint the unsaturated austenite of higher temperature becomes saturated with cementite and the latter is thrown out of solution. As the temperature continues to fall the austenite continues rejecting cementite until the second recalescent point Ar_1 is reached when austenite of eutectic composition remains and is changed bodily into pearlite. Pearlite then is the mixture of eutectic composition stable below the Ar_1 point and consists of a conglomerate of carbonless iron (ferrite) and iron carbide (cementite).

Figures 1*a* is a photomicrograph of an annealed hyper-eutectoid steel which has been highly polished and etched with a solution of nitric acid in alcohol in order to show the grain structure. Each irregular cell-like area is a grain cf this conglomerate, pearlite. The light network and areas between the pearlite grains represent the excess cementite above that required to form the eutectic and which was rejected to the grain boundaries as the steel cooled.

In the case of hypo-eutectoid steel (steel containing less than 0.87 per cent carbon) the iron or ferrite instead of cementite is in excess of that reouired for eutectic composition, consequently ferrite is thrown from solution as it cools through the critical range and the cooled steel consists of pearlite and ferrite. Figure 1*b*, shows a hypo-eutectoid steel in which the network and light areas are ferrite. The dark constituent is again pearlite.

"Proc. 38th Meeting, 1922 (1923)."

In ordinary annealed hyper-eutectoid steel inclusions are generally found within the cementite areas. In the case of hypo-eutectoid steel they usually occur in the ferrite grains and ferrite network surrounding



a b

c d

Fig. 1. a, Pearlite grains (dark) and cementite (light) in annealed hyper-eutectoid steel; b, pearlite grains (dark) and ferrite (light) in annealed hypo-eutectoid steel; c, inclusion surrounded by cementite in hyper-eutectoid steel; d, inclusions surrounded by ferrite in hypo-eutectoid steel, a and b etched with nitric acd, c and d with hydrochloric acid. x 80.

pearlite grains but rarely in the pearlite grains themselves. Figure 1*c* is a rather striking example of an inclusion surrounded by cementite in hyper-eutectoid steel. Figure 1*d*, shows a hypo-eutectoid steel. It

will be noted that practically all the inclusions occur in the light ferrite areas.

Segregation about inclusions cannot be destroyed by ordinary heat treatment, such as would break up ordinary grain formations. Besides being areas of little or no strength they then act as obstacles to the proper thermal treatment of the metal.

Whether inclusions are the cause of the segregation of cementite in hyper-eutectoid and ferrite in hypo-eutectoid steel or whether their co-existence is the result of some common and deeper seated cause has been the subject of considerable discussion.

Stead[1] pointed out that in the case of hypo-eutectoid steel the inclusions surrounded by ferrite generally occur in areas rich in phosphorus and he held that the phosphorus is the real cause of the ferrite segregation and that the presence of the inclusions is merely incidental. He believed that the inclusions themselves are not the cause of this segregation.

Howe[2] expressed the opinion that the presence of the inclusions within the ferrite or cementite areas is due to the tendency of the steel in the process of cooling to reject both inclusions and the ferrite or cementite to the grain boundaries.

Brearly[3] and Ziegler[4] suggested that the inclusions might act as nuclei for ferrite or cementite crystallization in a manner similar to a string suspended in a sugar solution.

Work in this laboratory[5] has led to the conclusion that the cause of ferrite and cementite segregation about inclusions is due to the fact that the inclusion itself or some reaction product of it with the surrounding steel is soluble to a slight extent in the metal at high temperatures and that this introduction of a third component into the solid solution system of iron and iron carbide so alters solubility relations that supersaturation is reached at a higher temperature in the metal immediately surrounding the inclusion than in the rest of the steel. If there is a zone, however narrow, lying about the inclusion and containing even a trace of any dissolved material from the inclusion, this foreign material should alter the solubility of the excess ferrite or cementite in the austenite next the inclusion and thus cause a local condition of supersaturation first in this region. The excess constituent then would separate here first. After separation had started it would continue about these spots as nuclei as the steel cooled farther and consequently the inclusions would be imbedded in the cementite or ferrite.

Under the direction of Dr. E. G. Mahin the writer undertook to study the effect produced upon cementite distribution in hyper-eutectoid steel when artificial inclusions of known composition were placed in the metal.

[1] J. Iron Steel Inst., *97*, 287 (1918).
[2] "The Metallography of Steel and Cast Iron", 280.
[3] Proc. Sheffield Soc. Eng. Metallurgists, 1919.
[4] Rev. metall., *8*, 655 (1911).
[5] J. Ind. Eng. Chem., *11*, 739 (1919).
Ibid., *12*, 1090 (1920).

Small blocks were cut from a bar of ordinary commercial high carbon steel of the following composition; carbon, 1.2; manganese, 0.30; phosphorus, 0.02; sulphur, 0.03; silicon, 0.20 per cent.

The method of preparing these specimens was the same as previously used in the study of inclusions in low carbon steel. This consisted in drilling holes through the blocks. At the same time rods of several alloys and special steels were turned on the lathe to a diameter slightly larger than the holes. After cleaning both rods and holes with an alcohol ether mixture the rods were driven into the holes and hammered until the contact between the two pieces was very intimate.

The alloy or special steel insert now occupied the same relation to the main body of high carbon steel as a natural inclusion might occupy in the same position.

The specimens so prepared were heated well above the transformation range of the steel for varying periods of time after which they were allowed to cool slowly in the furnace. After this treatment a section was cut from each specimen perpendicular to the axis of the insert so that the zone about the contact between it and the main body of the piece might be subjected to examination for evidence of cementite segregation.

In order to study in a more definite manner the effect upon carbon distribution produced by the localization of a few of the more common elements generally found in ordinary commercial steels inserts were made of several specially prepared steels.

Number 1 was a plain carbon steel containing about 0.5 per cent carbon. The other seven were of identical composition except that to each had been added some element in excessive amount. For example to number 2 had been added silicon and to number 3 phosphorus, etc. The amount of the added element found in each of the entire set follows:

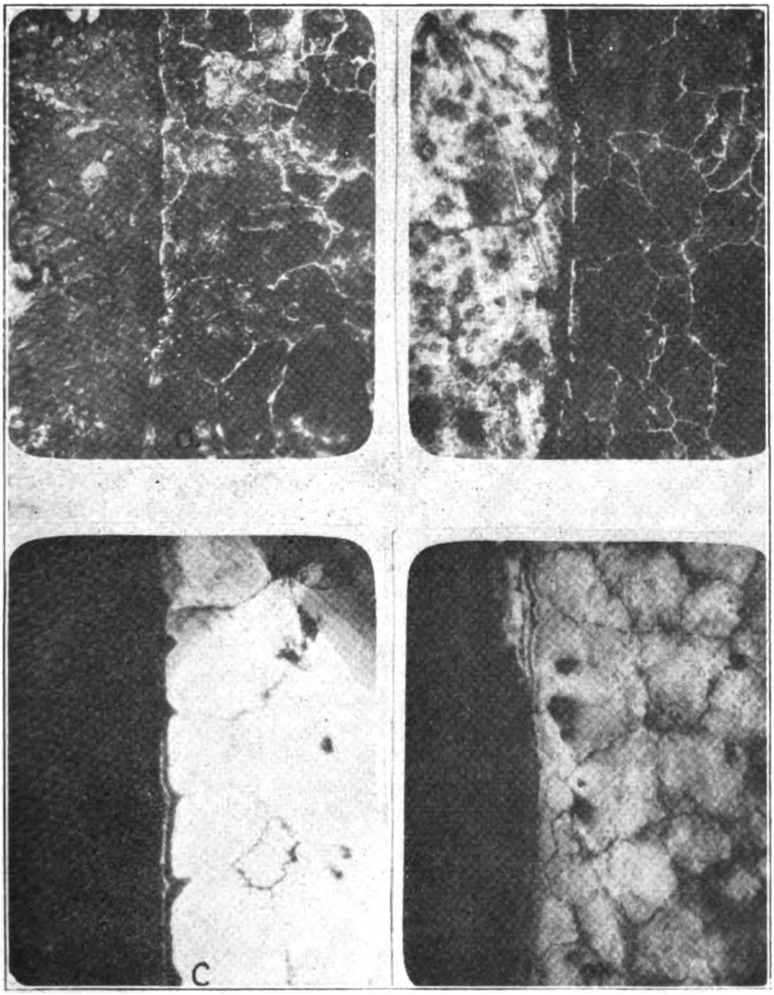
No. 1 Plain 0.5 per cent carbon steel.
No. 2 Plain 0.5 per cent carbon steel plus 4.0% silicon.
No. 3 Plain 0.5 per cent carbon steel plus 1.06% phosphorus.
No. 4 Plain 0.5 per cent carbon steel plus 1.46% manganese.
No. 5 Plain 0.5 per cent carbon steel plus 1.34% copper.
No. 6 Plain 0.5 per cent carbon steel plus 0.84% chromium.
No. 7 Plain 0.5 per cent carbon steel plus ...... titanium.
No. 8 Plain 0.5 per cent carbon steel plus 1.36% sulphur.

Several non-ferrous alloys also were used for inserts. Among them were alumel, an alloy of aluminium and nickel; copel, an alloy of copper and nickel; and chromel, an alloy of chromium and nickel.

The specimen with the insert of plain carbon steel and which contained no excessive amount of any element showed no tendency to cause the separation of cementite. It was found however that the diffusion from some of the other inserts into the adjacent steel had a tendency to cause cementite to segregate in this region while with other inserts containing other elements this tendency did not manifest itself under the conditions of the experiment. A few photomicrographs will show the nature of this effect.

Figure 2*b*, shows the appearance of the specimen containing the high silicon insert after it had been heated at 950°C. for three hours. There is a narrow but well defined band of cementite about the insert.

a b



c d

Fig. 2. a, Cementite segregated about high phosphorus insert in hyper-eutectoid steel; b, cementite segregated about high silicon insert in hyper-eutectoid steel; c, cementite segregated about alumel insert in hyper-eutectoid steel; d, cementite segregated about copel insert in hyper-eutectoid steel. a and b etched with nitric acid, c and d with sodium picrate. x 80.

The width of this zone corresponds to the depth to which the material from the insert had penetrated into the surrounding steel. This diffused material was probable iron silicide.

Figure 2*b*, shows the high-phosphorus insert. Here again the extent to which the phosphorus had penetrated into the steel is marked by a zone of cementite. This was heated at 900 for two hours.

The other steel inserts containing manganese, copper, chromium, titanium, and sulphur showed this tendency to cause cementite segregation to only a very limited extent or not at all.

Figure 2, *c* and *d*, respectively, show the specimens containing alumel and copel inserts. Cementite has collected about the insert in both cases. These specimens were etched with sodium picrate which causes cementite to appear dark.

From the results of these few experiments it would seem that inclusions in hyper-eutectoid steel must have a certain slight solubility in the austenite at high temperatures, and that the concentration of the dissolved matter is therefore greatest in the immediate vicinity of the inclusion. Such a condition of localized dissolved impurities probably has the effect of starting cementite crystallization first about the inclusion, thus breaking down the state of cementite supersaturation that always occurs in hyper-eutectoid steel cooling through the critical range. And since each inclusion is a center of contamination and furnishes a continuous supply of impurity to the surrounding steel no amount of heat treatment can eliminate its effect.

A STUDY OF, AND A MODIFIED METHOD FOR, VOGEL'S REACTION FOR COBALT.

F. J. ALLEN and A. R. MIDDLETON, Purdue University.

Among the more sensitive tests for cobaltous ion and one particularly suitable for detection of traces of cobalt in nickel salts is the reaction with thiocyanate, usually called Vogel's reaction. When an aqueous solution of a nickel salt, to which excess of ammonium thiocyanate has been added, is shaken with a mixture of equal parts of amyl alcohol and ethyl ether, even minute amounts of cobalt form a blue compound which dissolves in the ether-alcohol layer. Nickel remains entirely in the aqueous layer. Iron, if present in traces only, causes the color to appear purple but the interference of this element can be overcome as shown below. Although easily performed and requiring only reagents ordinarily available, especially in the modified procedure to be described, this test is mentioned in few textbooks of chemical analysis and seems to be not very widely known.

HISTORICAL. In 1877 Morrell[1] noted that cobalt salts, when added to a neutral or acid solution of ammonium thiocyanate in alcohol, give a blue color becoming pink on dilution. He proposed the use of this reaction for determining alcohol. Two years later Zimmerman[2] proposed a separation of iron from cobalt and nickel by excess of ammonium thiocyanate and precipitation of the iron as hydroxide by sodium carbonate solution added to the point of discharge of the red color of ferric thiocyanate. About the same time Wolff[3] studied the absorption spectra of cobalt thiocyanate solutions. Slightly later Vogel[4] proposed the reaction as a test for cobalt, removing iron by Zimmerman's method and dissolving the blue compound into a mixture of equal parts of amyl alcohol and ether. He stated that by the characteristic absorption spectrum of the blue ether-alcohol layer 1 part of $CoCl_2$ in 400 parts of $FeCl_3$ or in 200 parts of $NiCl_2$ could be detected easily.

Vogel's work remained practically unnoticed until 1900 when Treadwell[5] called attention to it and showed that the reaction is capable of detecting 0.02 mg. of cobalt in presence of large amounts of nickel. He also isolated the blue compound dissolved in the ether-alcohol layer and found its composition to be that of a double salt, $Co(SCN)_2 . 2NH_4SCN$. At about the same time Rosenheim and Cohn[6] by migration experiments showed that the blue compound contains a complex anion since cobalt migrated to the anode. They prepared nickel double thiocyanates in crystalline form having the general formula, $Ni(SCN)_2 . 4RSCN$, and found that in their solutions complex anions were not present, as nickel migrated only to the cathode. In Treadwell's Analytical Chemistry this reaction is included among the tests for cobalt. He prescribes neutral

[1] Z. analyt. Chem., 16, 251.
[2] Ber., 12, 2254.
[3] Ber., 12, 2314.
[4] Z. analyt. Chem., 18, 38.
[5] Z. anorg. Chem., 26, 108.
[6] Z. anorg. Chem., 27, 280.

solution and suppresses iron, when present, by ammonium acetate and tartaric acid.

In this laboratory it was observed some years ago that when ethyl alcohol is substituted for amyl alcohol and potassium thiocyanate for the ammonium salt, a blue color is developed in the aqueous layer which does not pass into the ether layer until mineral acid is added. It was found that under these conditions cobalt could be readily detected in nickel salts in which the procedure recommended by Treadwell failed to show the presence of this element. Of many salts examined only one, a Kahlbaum's "kobalt-frei" $NiSO_4$, failed to show the presence of cobalt. Since nickel salts usually contain iron, a purple instead of blue color appeared in the ether layer. It was found that shaking with a few small crystals of sodium thiosulfate quickly reduced the iron and a pure blue color remained.

It appeared desirable to study this modification of the Vogel reaction in greater detail in order to fix more certainly the conditions of concentration under which it is most delicate and reliable and to compare the delicacy of the test in neutral and in acid solution. It seemed probable that in acid solution the blue ether-soluble compound might be the acid of a complex anion, e.g., $H_2Co(SCN)_4$, and that such an acid might be isolated from the ether solution. Two such complex acids have been obtained in crystalline form, $H_2Hg(SCN_4)$[1] and $HAu(SCN)_4.2H_2O$.[2]

EXPERIMENTAL. A solution of cobalt nitrate was prepared by dissolving electrolytic nickel-free cobalt in nitric acid, removing excess of acid by evaporation and diluting with water. This solution was standardized (1) by igniting the nitrate and weighing as Co_3O_4; (2) by conversion to anhydrous sulfate. The cobalt content per cc. as found by the first method was 8.401 mg. and by the second 8.391 mg.; average, 8.396 mg. By accurate dilution solutions were prepared containing respectively, 1.0, 0.1, 0.01 and 0.001 mg. of cobalt per cc. Standard solutions of ammonium, potassium and sodium thiocyanates and of hydrochloric and sulfuric acids were also prepared.

A. *Treadwell-Vogel Test* (*Neutral solution*). The effect of varying the concentrations of the various components of the test solution was studied and the conditions determined under which the test is most delicate. The optimum conditions were found to be high concentration of thiocyanate, small total volume and small volume of the ether-alcohol layer. For example, 5cc. of 4 normal Na, K, or NH_4 thiocyanate, 2.5 cc. of saturated ammonium acetate and 0.5 cc. of cobalt nitrate (0.001 mg. per cc. Co) when shaken with 1 cc. of 1:1 mixture of amyl alcohol and ethyl ether gave a faint but distinct blue color in the ether-alcohol layer when this was observed against a white background. Under these conditions 0.0005 mg. of Co in a total aqueous volume of 8 cc. is clearly detectable. Treadwell's statement that 0.02 mg. of cobalt is detectable is conservative. Not much difference was observed in the effectiveness of the three alkali thiocyanates but it was noticed that

[1] Rosenheim and Cohn, loc. cit.

[2] Bjerrum and Kirschner, Die Rhodanide des Goldes—Mem. acad. roy. sci. lettres Danemark, 8me serie, V, No. 1, p. 20.

traces of iron interfered less when the sodium salt was used. This is in accord with the observation of Rosenheim and Cohn[1] that of the three alkali-ferric thiocyanates, $R_3Fe(SCN)_6$, prepared by them the sodium salt is most stable and least decomposed by aqueous ether into $Fe(SCN)_3$, which is soluble in ether and NaSCN insoluble in ether.

B. *The Vogel Test in acid solution.* The effect of varying a single component of the test solution while keeping the others constant is shown in the tables following.

TABLE 1. Effect of acid concentration.

0.01 mg. Co, 1 cc. 4 N NH_4SCN, 0.3 cc. C_2H_5OH, 1.2 cc. $(C_2H_5)_2O$; total volume 5 cc.

H_2SO_4 normality in 5 cc.	Color in alcohol-ether layer	HCl normality in 5 cc.	Color in alcohol-ether layer
0.0	none	0.0	none
0.2	faint blue	0.2	faint blue
0.4	faint blue	0.4	faint blue
0.6	deeper blue	0.6	deeper blue
0.8	maximum blue	0.8	maximum blue
1.0	maximum blue	1.0	maximum blue
1.5	maximum blue	1.5	maximum blue
3.0	weaker blue	3.0	weaker blue
6.0	pale blue	5.0	none
9.0	greenish blue		

TABLE 2. Effect of thiocyanate concentration.

0.01 mg. Co, 0.8 cc. 5 N HCl, 0.3 cc.C_2H_5OH, 1.2 cc. $(C_2H_5)_2O$; total vol., 5cc.

Normality of thiocyanate in 5 cc.	Color in alcohol-ether layer
0.0	none
0.08	none
0.4	faint blue
0.8	maximum blue
1.36	maximum blue

[1] Loc. cit.

TABLE 3. Effect of ethyl alcohol.

0.01 mg. Co, 1cc. 4 N NH_4SCN, 0.8 cc. 5N HCl, 1 cc. ether; total vol. 5 cc.

Per cent alcohol in 5 cc.	Color in ether or ether-alcohol layer.
0.0	faint blue
1.0	slightly bluer
2.0	slightly bluer
4.0	maximum blue
6.0	maximum blue
8.0	maximum blue
16.0	maximum blue
20.0	maximum blue

TABLE 4. Limit of sensitiveness.

1 cc. 4 N NH_4SCN, 1 cc. 5 N HCl, 0.3 cc. alcohol, 1.2 cc. ether: total vol. 5 cc.

mg. Co	Color, ether-alcohol layer
0.0	none
.001	very faint blue
.002	pale blue
.003	pale blue
.004	clear, sky blue

Repetition using KSCN and NaSCN in place of NH_4SCN gave the same tints for each concn. of Co.

TABLE 5. Comparison of sodium, potassium and ammonium thiocyanates in neutral solution.

1 cc. 4 N alk. thiocyanate, 2 cc. ether, 0.5 cc. C_2H_5OH; total vol. 5 cc. (The sodium and potassium salts gave identical results).

mg. Co	Color, KSCN or NaSCN		Color, NH_4SCN	
	aqueous layer	ether layer	aqueous layer	ether layer
0.1	sky blue	none	sky blue	very faint blue
1.0	deep blue	very faint blue	deep blue	deep blue
1.5	deep blue	pale blue	deep blue	deep blue
55.0	indigo blue	deep sky blue	indigo blue	slightly paler than aqueous layer

TABLE 6. Comparison of 1:1 amyl alcohol-ether with 1:4 ethyl alcohol-ether in acid solution.

1 cc. 4 N NH_4SCN, 1 cc. 5 N HCl; total vol. 5 cc.

mg. Co	Color, amyl alcohol-ether	Color, ethyl alcohol-ether
0.001	none	faint blue
.002	faint blue	distinct blue

TABLE 7. Ethyl alcohol in neutral solution as a reagent for cobalt.

1 cc. 4 N NaSCN; total vol. 5 cc.

Per cent C_2H_5OH in total volume	Color 0.01 mg. Co	Color 0.1 mg. Co
20	none	none
30	barely perceptible blue	pale blue
40	pale blue	bright blue
50	pale blue	bright blue
60	pale blue	bright blue

Discussion of Results. Table 1 shows that the maximum color is developed when the solution is at least 0.8 normal in acid and that increase of acid concentration up to 1.5 normal is without effect. Weakening or disappearance of the blue color at acid concentrations above 3 normal is to be expected if the blue compound is a complex anion. By forming little ionized HSCN high concentration of hydrogen ion should tend to decompose the blue complex and this decomposition should be proportional to the concentration of mineral acid.

Table 2 shows that the thiocyanate concentration should be at least 1 normal and that concentrations above this do not increase the sensitiveness of the test.

Table 3 shows that when the aqueous layer contains only 4 per cent ethyl alcohol the solubility of the blue compound in ether reaches a maximum and that increase of alcohol concentration up to the point where an ether layer no longer separates does not cause any increase of sensitiveness.

Table 4 shows that in acid solution the three alkali thiocyanates used are equally effective as would be expected. Under the optimum conditions of concentration 0.001 mg. of cobalt is detectable in 5 cc. of solution. In neutral solution, however, as appears from table 5, the ammonium complex salt is distinctly more soluble in ether than the sodium or potassium salts. That addition of a little mineral acid to the blue aqueous layer drives all the blue compound into the ether layer is evidence that the ether-soluble compound is a complex acid and not a salt, such as $Co(SCN)_2$ or $Na_2Co(SCN)_4$. Additional evidence upon this point will be presented in another paper.

Table 6, which compares the effectiveness of amyl alcohol-ether, 1:1, used with neutral aqueous solution of ammonium thiocyanate, with 1:4 ethyl alcohol-ether, used with aqueous solution of any alkali thiocyanate 1 normal in mineral acid, shows that the greater solubility in ether of the free complex acid as compared with that of the ammonium salt makes the test slightly more delicate when performed in acid solution. In presence of large quantities of nickel salts this advantage becomes still more marked. In acid solution the interference of ferric iron is considerably greater but this is quickly and easily reduced by shaking with a few crystals of sodium thiosulfate which does not affect at all the reaction with cobalt.

Table 7 shows that in water-alcohol mixtures fairly high in alcohol quite small amounts of cobalt are able to give a distinct color. As the solutions here were neutral, the sodium complex salt must be assumed present. Under these conditions, however, the green color of nickel salts would interfere with the detection of small amounts of cobalt.

Summary.

1. Treadwell's method of carrying out the Vogel test for cobalt in neutral solution using equal parts of ether and amyl alcohol was studied by varying the components of the reaction mixture one by one while keeping the others constant. The optimum conditions were found to be high concentration of thiocyanate, small aqueous volume and small

volume of the ether-alcohol mixture. As little as 0.001 mg. of cobalt in 8 cc. can be detected under these conditions. If only traces of iron are present, it causes less interference when NaSCN is used than when the ammonium salt prescribed by Treadwell is used. The interference of larger quantities of iron is not very satisfactorily overcome by ammonium acetate and tartaric acid.

2. In acid solution and using a small amount of ethyl instead of amyl alcohol the test is at least equally delicate. The optimum conditions were found to be concentrations of thiocyanate and of H_2SO_4 or HCl about 1 normal each and addition of ethyl alcohol equal to about 5 per cent by volume of the aqueous layer and no more ether than required to form a separate layer. In acid solution ferric iron is readily and quickly reduced by shaking with a few crystals of sodium thiosulfate. Even moderately large amounts of iron cause no interference with the test for cobalt. The easy removal of interference by iron, the more general availability of ethyl as compared with amyl alcohol, and that any one of the alkali thiocyanates may be used are features which recommend the test in acid solution as a preferable modification.

THIOCYANATOCOBALTOUS ACID AND ITS ALKALI SALTS.

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When an aqueous solution of $K_2Co(SCN)_4$, to which sufficient KSCN has been added to make the solution 0.8-1.0 normal in thiocyanate, is shaken with sufficient 1:4 ethyl alcohol-ether to form a separate layer, only traces of a blue compound pass into the ether layer. If the solution be now acidified with mineral acid, practically all the blue compound passes into the ether layer. As the blue color has been shown by Rosenheim and Cohn[1] to be due to a bivalent complex negative ion, $Co(SCN)_4''$ it appears probable that in the acid solution the free acid, $H_2Co(SCN)_4$, may be formed which is readily soluble in ether while its potassium salt is nearly insoluble. Two similar acids, $H_2Hg(SCN)_4$[2] and $HAu(SCN)_4 . 2H_2O$,[3] have been isolated in solid, crystalline form. Preliminary attempts to isolate the acid in solid form, by evaporation of the ether solution in an evacuated desiccator, showed that large amounts of HSCN were evolved as the solution concentrated. A mixture was deposited consisting of long slender needles of deep blue color which showed a strong acid reaction when moistened with water and short needles of a bluish green color. No method of separating the two sufficiently for analysis has been found up to this time. In order to obtain some information as to the nature of the ether-soluble blue compound, experiments were made to determine the partition of acid, thiocyanate and cobalt between the aqueous and ether layers at 25° C.

Preliminary determinations were made of the partition of sulfuric acid and of thiocyanic acid. These are recorded in the following tables.

TABLE 1. Partition of H_2SO_4 between water and 1:4 alcohol (EtOH)-ether (Et_2O).

	Normality of acid.	
Expt. No.	Aq. layer	Et_2O Layer
1	0.8005	0.0037
2	1.7112	0.0074

The solubility of H_2SO_4 in aqueous ether is very small and in comparison with the large solubility of HSCN shown in the next table is negligible at total concentrations not above 1.5 normal.

[1] Z. anorg. Chem., 27, 280 (1900).
[2] Rosenheim and Cohn, loc. cit.
[3] Bjerrum and Kirschner, Die Rhodanide des Goldes, Mem. acad. roy. sci. lettres, Danemark, 8me serie, V, No. 1, p. 20.

TABLE 2—Partition of HSCN between water and 1:4 $EtOH\text{-}Et_2O$.

In each experiment 10 cc. 4 normal NaSCN (SCN = 0.04 equiv.)

Expt. No.	5-N. H_2SO_4 cc.	Volume cc.		Acid normality		SCN normality		Ratios		
		aq.	Et_2O	aq.	Et_2O	aq. (by dif.)	Et_2O	Et_2O H^+ to aq. H^+	Et_2O SCN to aq. SCN	Et_2O SCN to Et_2O H^+
1	0	*	*	0.0	0.0	....	0.0087	....	....	....
2	1	32	26	.0440	.1651	1.108	.1744	3.75	0.157	1.056
3	3	26.5	24.5	.1908	.4801	1.042	.5060	2.52	.486	1.054
4	5	24	24	.3890	.7230	0.9078	.7590	1.86	.836	1.050
5	7	22	24.5	.6680	.9360	.7736	.9380	1.40	1.212	1.002
6	9	19	25	1.082	1.098	.5850	1.155	1.15	1.974	1.052
7	20	32	30	2.280	1.122	.1625	1.160	0.49	7.139	1.034

*Not recorded.

In the above table, experiment 1 shows that NaSCN has a very small but appreciable solubility in aqueous ether. Unfortunately, the volumes of the aqueous and the ether layers in this experiment were not recorded so that the ratios in the last column could not be corrected for dissolved salt. The slight excess of thiocyanate is undoubtedly due to this cause. The close approximation of the last ratio to unity shows that the ether-soluble substance is practically all HSCN. The data clearly show that this acid is far more soluble in ether than in water. A small excess of mineral acid is sufficient to force nearly all the thiocyanate into the ether layer as HSCN.

The data recorded in table 3 were obtained as follows. In a tall glass-stoppered cylinder were placed 25 cc. of an aqueous solution of $K_2Co(SCN)_4$ in which the cobalt content was 71.0 mg., 10 cc. of 4 normal KSCN, the recorded volumes of 5 normal H_2SO_4, (in Expt. 9, 5 cc. of 33 normal acid) and sufficient 1:4 ethyl alcohol-ether to give approximately equal layers. The cylinder was placed in a bath at 25° C. and frequently shaken until equilibrium was reached. In separate portions of the ether layer acidity was determined by titration with NaOH and phenolphthalein, SCN by titration with $AgNO_3$ and ferric alum, and cobalt by evaporation with H_2SO_4 and weighing as $CoSO_4$. Acid in the aqueous layer was also determined. In experiment 9, only 20 cc. of the $K_2Co(SCN)_4$ solution were taken.

The ratio ½Co:SCN, together with the data of columns 8 and 12, indicates a small solubility of $Co(SCN)_2$ in aqueous ether containing a little alcohol. This was confirmed using a sample of the purple $Co(SCN)_2 3H_2O$ which, although not very pure as shown by analysis, showed all the reactions of this salt. When placed in ether the latter assumed only a faint tinge of blue. The solubility calculated from the data of experiment 1 is 0.347 mg. per cc. for the anhydrous salt.

The ratios, H^+:½Co:SCN and (SCN-½Co): H^+, confirm the conclusion from table 2 that HSCN is largely soluble in ether and that its concentration in the ether layer increases rapidly as the mineral acid in the aqueous layer is increased.

The data throw no light on the formula of the ether-soluble, blue cobalt compound. In not too acid solutions about 20 mols. of HSCN for each mol. of $Co(SCN)_2$ are present. This may indicate either a

TABLE 3. Partition of Co and HSCN between water and 1:4 alcohol-ether. In each experiment 10 cc. 4 N KSCN. In experiments 1-8, 71.0 mg. Co=0.020404 equiv.; total SCN=0.080808 equiv. In experiment 9, 0.016323 equiv. Co and 0.072646 equiv. SCN.

Expt. No.	5—N H_2SO_4 cc.	Volume cc.		Acid normality		SCN normality		$CoSO_4$ mg. per cc.		Cobalt normality		Ratio in Ether layer			Ratio		Fraction of total Co in Et_2O layer
		aq.	Et_2O	aq.	Et_2O	aq. by dif.	Et_2O	aq. by dif.	Et_2O	aq. by dif.	Et_2O	H^+ to	½ Co	to SCN	(SCN—½ Co)	to H^+	
1	0	51	42	0.0	0.0	1.581	0.004	3.402	0.312	0.0439	0.004	0.0	1	1	—	—	—
2	1	50	44	0.0330	0.0945	1.521	0.109	3.020	0.808	0.0389	0.0104	9.086	1	10.48	1	1.0435	0.211
3	3	49	48	0.0945	0.2496	1.367	0.288	1.986	1.860	0.0256	0.0240	10.04	1	12.00	1	1.058	0.4837
4	5	49	48	0.2090	0.3590	1.265	0.392	1.308	2.552	0.0168	0.0329	10.91	1	11.91	1	1.0003	0.661
5	7	50	48	0.363	0.4476	1.135	0.502	0.764	3.092	0.0099	0.0398	11.24	1	12.60	1	1.0310	0.802
6	9	51	46	0.495	0.5280	1.030	0.593	0.571	3.424	0.0074	0.0442	10.94	1	13.39	1	1.0395	0.857
7	11	53	45	0.646	0.580	0.984	0.637	0.641	3.392	0.0083	0.0438	13.24	1	14.54	1	1.1023	0.841
8	15	55	44	0.910	0.653	0.865	0.755	0.705	3.360	0.0091	0.0438	14.90	1	17.21	1	1.089	0.827
9	5 cc. 33 N	35	57	3.630	0.770	0.797	0.785	1.574	1.652	0.0203	0.0213	36.15	1	36.80	1	0.992	0.512

definite compound, $H_{2x}Co.(SCN)_{4x}$, a mixture of several such acids, or an acid of definite formula along with a large excess of HSCN. That upon evaporation the ether solution deposits deep blue crystals having a strong acid reaction makes it probable that a definite acid, $H_{2x}Co.(SCN)_{4x}$, is present and that it is capable of existence in solid crystalline form. The problem of obtaining this compound sufficiently pure for analysis is being further investigated.

The conclusion drawn from table 1 of the preceding paper on Vogel's reaction, that the fraction of cobalt which passes into the ether layer reaches a maximum at moderate concentrations of mineral acid and then decreases as the acid is increased, is clearly verified by the data of table 3 above, as shown in the last column.

Alkali salts of Thiocyanatocobaltous Acid. Deep blue double thiocyanates of cobalt and alkali metals have been prepared in crystalline form by Treadwell[1] and by Rosenheim and Cohn.[2] These investigators agree in assigning to these salts the empirical formula, $Co(SCN)_2.2RSCN$, in which R may be NH_4, K or Na, but they differ as to their properties and hydration. By transference experiments Rosenheim and Cohn proved that the blue color was due to a complex anion, $Co(SCN)_4''$. Treadwell, working with organic solvents, obtained the potassium and ammonium salts in anhydrous condition and found them to be quickly decomposed by water and even by moist air. Rosenheim and Cohn prepared 12-14% solutions of HSCN by action of H_2S on concentrated solutions of $Hg(SCN)_2$ and by action of this acid on $CoCO_3$ prepared cobalt thiocyanate in violet rhombic crystals of composition $Co(SCN)_2.3H_2O$. By addition of the calculated amounts of the various alkali thiocyanates to aqueous solutions of this salt they obtained in well defined crystalline form the potassium and ammonium salts, each with 4 molecules of water, and the Na and Ba salts each with 8 molecules of water. They found all these salts to be soluble in methyl, ethyl and amyl alcohol and in acetone and that they could be recrystallized from concentrated aqueous solution without decomposition. They also prepared the anhydrous salts by Treadwell's methods and from aqueous solutions of these obtained the hydrated salts without decomposition. It seemed worth while to investigate these discrepant statements.

A simpler method of preparing the potassium salt and also $Co(SCN)_2.3H_2O$ was worked out. The work described below verifies the statements of Rosenheim and Cohn but it was found that the tri-hydrate is the form of the potassium and ammonium salts which is stable in air at the temperature of the laboratory, although, as stated by Rosenheim and Cohn, the tetra-hydrate separates from aqueous solution. The loss of one molecule of water is not accompanied by any change in the appearance of the crystals. The sodium complex salt was not prepared.

EXPERIMENTAL.

To concentrated aqueous solution of $CoSO_4$ was added the amount of KSCN calculated to form the double salt and then ethyl alcohol in

[1] Z. anorg. Chem., 26, 108 (1900).

[2] Loc. cit.

large excess. Most of the K_2SO_4 precipitates and can be filtered off. The deep-blue alcoholic solution was evaporated on a water bath nearly to dryness and alcohol added. More K_2SO_4 could now be removed and three or four repetitions of this process proved sufficient for the complete removal of sulfate. The sulfate-free alcoholic solution was evaporated with occasional additions of a little water until the alcohol was removed and the concentrated aqueous solution allowed to crystallize at room temperature. Crystals of the potassium salt several centimeters long were thus obtained. Analysis of the crystals, removed from the mother liquor and dried by pressing between filter paper, gave: SCN=52.65%; Co=13.53%. $K_2Co(SCN)_4.4H_2O$ requires SCN=52.61; Co=13.35.

After exposure to air: 24 hours, SCN=54.99%; Co=13.69%; 96 hours, SCN=55.09%, Co=14.29%; 144 hours, SCN=55.15%, Co=14.04%. $K_2Co(SCN)_4.3H_2O$ requires SCN=54.85%, Co=13.92%. Evidently the trihydrate, and not the tetrahydrate, is the form stable in air at room temperature.

The ammonium complex salt was prepared in anhydrous form by precipitation from its acetone solution by chloroform and dried in air. Found, SCN=69.17%; $(NH_4)_2Co(SCN)_4$ requires SCN=70.97%. The salt was dissolved in water and the solution, when evaporated at low temperature, yielded fine blue needles often several centimeters long. This material, when removed from the mother liquor and dried by pressing between filter paper, gave SCN=60.75%; after exposure to air 48 hours, 60.44%; after 72 hours, 61.03%; after 96 hours, 61.22%. The tetrahydrate requires SCN=58.16%; the trihydrate requires SCN=60.91%. The trihydrate appears to be the form of the ammonium salt also which is stable in air at room temperature.

By the same method of removal of alkali sulfate by alcohol it was found possible to obtain the purple $Co(SCN)_2.3H_2O$ by adding to concentrated aqueous solutions of $CoSO_4$ the calculated amount of NaSCN. The product was well crystallized and contained only a spectroscopic trace of sodium. In appearance and reactions it corresponded exactly with the description of Rosenheim and Cohn but analysis gave Co=22.17%, SCN=54.19%. $Co(SCN)_2 3H_2O$ requires Co=25.77%, SCN=50.66%. This salt is unstable in air and passes into a yellow-brown substance, readily soluble in alcohol to a deep-blue solution and in appearance corresponding to the hemihydrate, $Co(SCN)_2.\frac{1}{2}H_2O$, described by Rosenheim and Cohn.

Summary.

1. The partition of cobalt between water and aqueous-alcoholic-ether in presence of thiocyanic acid was studied. The ether layer was found to contain equivalent proportions of cobalt and thiocyanate, in addition to large amounts of thiocyanic acid, but to dissolve practically no cobalt thiocyanate or alkali thiocyanate.

2. The data obtained in this study do not permit definite conclusion as to the formula, or formulas, of the extremely ether-soluble blue cobalt compounds, although the evidence makes it highly probable that one or more complex acids having cobalt in the anion are present.

3. Both the blue complex alkali thiocyanatocobaltites and the purple trihydrate of cobalt thiocyanate can be prepared by double decomposition in aqueous solution starting from the sulfate of cobalt and removing alkali sulfates by means of alcohol. This simple method avoids the use of thiocyanic acid which is not easy to prepare in at all concentrated solution and is rather unstable in aqueous solution.

4. It is shown that at laboratory temperature the trihydrate, and not the tetrahydrate, is the form stable in air for the ammonium and potassium thiocyanatocobaltites. In all other respects the statements of Rosenheim and Cohn were confirmed. Treadwell is in error as to the instability of these salts. That the purple trihydrate of cobalt thiocyanate changes into the yellow-brown hemihydrate rather rapidly when exposed to the air of an artificially warmed room has not been previously recorded.

EVAPORATION OF SOLUTIONS AND LIQUIDS IN BURETTES.

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In very accurate titrametric analyses cne may weigh the amount of standard solution reacting with the constituent being determined and from the weight of solution used calculate the percentage of the constituent, providing the concentration of the standard solution has been determined upon a weight basis. This procedure avoids the possible errors arising from a change of temperature and from evaporation, if the standard solution is measured rather than weighed. The volumetric method of determining the amount of solution is, however, the one generally employed.

In the event of a distinct change occurring in the temperature of the standard solution during a determination, which means a corresponding change in the volume of the solution, one needs only to note the variation of temperature and then to consult tables for the proper correction in volume. These tables have been prepared for various solutions of various concentrations.

The error arising from evaporation of the solvent of a standard solution and the consequent increase in concentration of solute per unit volume is not so readily found in the usual works of reference on quantitative chemical analysis. The experiments reported at this time were made with the object of obtaining information regarding the rate of evaporation of solutions and liquids in burettes.

Factors Affecting the Rate of Evaporation. No previous work has been found relating directly to the effect upon the accuracy of analytical data resulting from the loss, through evaporation, of the solvent of standard solutions standing in burettes. Many papers have appeared, however, dealing with the general subject of evaporation and with the laws relating to the process,[1] but we are here concerned with a consideration only of the factors affecting the systems now being studied. From these papers just mentioned and from others dealing with certain aspects of the physico-chemical theory of solutions and liquids, a number of facts may be summarized as having a direct bearing upon the present work.

All liquids tend to assume the gaseous phase, and the measure of this tendency is known as the vapor tension of the liquid. For a given liquid there corresponds to each temperature a certain definite pressure of its vapor. This vapor pressure is defined as that pressure at which the rate of escape into the gaseous phase of the liquid molecules is ex-

[1] Livingston—Monthly Weather Report—U.S.A.—1909. "An Annotated Bibliography on Evaporation."
Vaillant—Compt. rend. *146*, 582, 811; *148*, 1099; *150*, 213.
Jablczynski and Prezmyski—J. chim. phys. *10*, 241.
Marcelin—*Ibid.*—*10*, 680.
Marcelin—Compt. rend. *158*, 1674.
Thomas and Ferguson—Phil. Mag. *34*, 308 (1917).
Burger—Proc. Acad. Sci. Amsterdam—*21*, 271 (1919).
Weiser and Porter—Jr. Phys. Chem.—*24*, 333 (1920).

"Proc. 38th Meeting, 1922 (1923)."

actly balanced by the return into the liquid phase of the gaseous molecules. In the event that the system under consideration is not closed and that the rate of escape of the liquid molecules over-balances the rate of return of the gaseous molecules, the equilibrium otherwise prevailing is disturbed and the liquid evaporates.

The rate of the process of evaporation is then subject to several variable factors. In the case of liquid water, for example, exposed in an open vessel to the atmosphere, the rate of evaporation is directly proportional to the velocity of air currents, to the radius of the exposed surface, and to the vapor tension of the liquid. The latter is in turn directly proportional to the temperature. Further, the rate is inversely proportional to the distance of the surface of the liquid from the rim of the containing vessel, to the relative humidity or partial pressure of aqueous vapor of the atmosphere, and to the barometric pressure. Various "laws of evaporation" have been proposed in the effort to connect these variables with the rate of evaporation. Some of the expressions developed include such constants as the molecular weight of the liquid and the latent heat of vaporization, if the rate is to be stated in terms of mass of liquid evaporated per unit time.

In the case of solutions there must be considered also the variation of the vapor pressure of the solvent with the amount of the dissolved solute. It is well known that the vapor pressure of a solvent is lowered by the addition of a soluble salt, for example, and that the retardation in the rate of evaporation thereby produced is proportional to the amount of salt dissolved. Furthermore, it has been shown recently that loss of solvent by evaporation of equimolar solutions is least with salts that give the greatest number of ions.

Experimental Procedure. The burettes used in this work were of the type recommended by the Bureau of Standards, and were sealed off at the bottom in order to prevent any error from leakage. Two sets were arranged, the individual members being chosen as nearly as possible with the same inside diameters. Over the "open" set was suspended a cover about 10 cm. from the ends of the burettes in order to protect them from falling particles of dust. Over the ends of the "covered" set were placed ends of test tubes, 6 cm. long, to serve as caps.

The temperature at the time of reading the burettes was taken from a thermometer suspended among them. A sling psychrometer was used for determining the relative humidity of the atmosphere according to the method of the U. S. Weather Bureau. The barometric readings are uncorrected.

Working under the conditions of experimentation stated, determinations have been made of the effect upon the rate of evaporation of (a) the size of the burette, (b) the concentration of solutions, and (c) the presence of caps over the ends of the burettes. For the study of (a) several liquids having distinctly different vapor tensions were selected—water, benzene and toluene; for (b) a series of standard solutions of sodium chloride in water were prepared by dissolving the proper weight of salt; and for (c) parallel series were run for (a) and (b)—one set covered and the other open.

For any given series of readings the burettes were filled and the solutions allowed to attain the temperature of the room. In order to have the surfaces of the solutions in the several burettes all the same distance from the top at the beginning, a siphon extending down 10 cm. from the rim was used to remove any solution or liquid above this point. After a few minutes the first reading was made. The others were taken on the mornings of succeeding days, before the small laboratory was opened and the temperature had an opportunity to change much. The sets were only partially protected from currents of air.

This method of procedure does not furnish data on the actual rate of evaporation for any definite conditions, as no attempt was made to hold any of the variable factors constant during the determinations; but it does furnish one with an approximate idea of the error involved as a result of evaporation of standard solutions under the usual conditions prevailing in the laboratory.

The following tables include the data obtained for solutions of sodium chloride of various concentrations, water, benzene and toluene. The total loss in milliliters is given for the various intervals of time.

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TABLE 1. Evaporation of Liquids in Burettes of Different Capacities.

Time days	Temp. degrees C.	Relative Humidity	Barometric Pressure mm.	10 ml. Open	10 ml. Covered	25 ml. Open	25 ml. Covered	50 ml. Open	50 ml. Covered	100 ml. Open	100 ml. Covered
WATER											
1	21.5	53	752.5	0.01	**0.01**	0.01	**0.00**	0.02	**0.01**	0 02	**0.01**
2	24.5	31	756.0	0.02	**0.01**	0.02	**0.00**	0.01	**—0.01**	0.00	**—0.02**
3	23.0	30	748.7	0.04	**0.03**	0.05	**0.02**	0.07	**0.02**	0.08	**0.02**
4	23.0	54	746.2	0.07	**0.04**	0.10	**0.05**	0.12	**0.06**	0.20	**0.10**
5	18.0	57	744.4	0 09	**0.05**	0.12	**0.07**	0.14	**0.08**	0 24	**0.12**
6	22.0	37	751.1	0.09	**0.06**	0.13	**0.07**	0 15	**0.08**	0.25	**0.13**
7	23.5	23	754.3	0.11	**0.07**	0.16	**0.07**	0.15	**0.07**	0.20	**0.08**
8	25.0	26	753.8	0.12	**0.08**	0.18	**0.08**	0.16	**0.06**	0.20	**0.06**
9	22.5	33	754.5	0.15	**0.10**	0.22	**0.11**	0.22	**0.12**	0.34	**0.16**
10	19.0	39	751.3	0.18	**0.12**	0.26	**0.13**	0.27	**0.17**	0.46	**0.28**
12	21.0	39	744.8	0.20	**0.14**	0 31	**0.16**	0.32	**0.19**	0.50	**0.30**
14	20.0	31	748.7	0.25	**0.17**	0.37	**0.19**	0.38	**0.23**	0.64	**0.36**
BENZENE											
1	23.5	33	748.5	0.22	**0.16**	0.37	**0.20**	0.34	**0.23**	0.58	**0.34**
2	23.5	38	755.3	0.44	**0.31**	0.68	**0.39**	0.64	**0.44**	1.14	**0.70**
3	22.0	33	756.0	0.66	**0.49**	1.06	**0.64**	1.07	**0.77**	1.90	**1.30**
4	18.0	44	751.4	0 89	**0.67**	1.44	**0.91**	1.51	**1.13**	2.72	**1.96**
5	18.5	53	752 2	1.06	**0.80**	1.69	**1.06**	1.72	**1.29**	3.08	**2.22**
TOLUENE											
1	23.5	32	753.0	0.07	**0.06**	0.10	**0.06**	0.10	**0.07**	0.16	**0.08**
2	24.0	24	746.2	0.13	**0.09**	0.18	**0.10**	0.18	**0.11**	0.30	**0.16**
3	24.0	22	747.0	0.20	**0.14**	0.30	**0.18**	0.30	**0.19**	0.52	**0.30**
4	19.0	29	752.0	0.29	**0.22**	0.49	**0.32**	0.58	**0.44**	1.02	**0.74**
Diameter of Burettes in cm.				0.86	0.86	1.08	1.08	1.06	1.06	1.24	1.24

TABLE 2. Evaporation of Aqueous Solutions of Sodium Chloride of Different Concentrations in Burettes of the Same Capacity.

Time days	Temp. degrees C.	Barometric Pressure mm.	Relative Humidity	Water		0.25 N		0.50 N		0.75 N		1.00 N		2.00 N		5.00 N	
				Open	Covered	Open	Covered	Open	Covered	Open	Covered	Open	Covered	Open	Covered	Open	Covered
1	21.5	752.5	53	0.01	**0.00**	0.01	**0.00**	0.01	**0.00**	0.02	**0.01**	0.02	**0.00**	0.01	**0.00**	0.00	**0.00**
2	24.5	756.0	31	0.01	**—0.01**	0.00	**—0.03**	0.00	**—0.03**	—0.01	**—0.03**	—0.01	**—0.04**	—0.03	**—0.05**	—0.07	**—0.07**
3	23.0	748.7	30	0.06	**0.02**	0.04	**0.00**	0.04	**0.02**	0.04	**0.03**	0.05	**0.00**	0.02	**0.00**	—0.01	**—0.02**
4	23.0	746.2	54	0.11	**0.06**	0.09	**0.04**	0.10	**0.05**	0.10	**0.08**	0.11	**0.04**	0.09	**0.05**	0.05	**0.03**
5	18.0	744.4	57	0.14	**0.08**	0.13	**0.07**	0.13	**0.09**	0.14	**0.10**	0.14	**0.07**	0.12	**0.08**	0.09	**0.07**
6	22.0	751.1	37	0.14	**0.08**	0.13	**0.07**	0.14	**0.09**	0.14	**0.11**	0.14	**0.07**	0.12	**0.08**	0.09	**0.07**
7	23.5	754.3	23	0.14	**0.07**	0.13	**0.05**	0.13	**0.05**	0.13	**0.06**	0.12	**0.02**	0.09	**0.02**	0.02	**—0.01**
8	25.0	753.8	26	0.14	**0.06**	0.13	**0.04**	0.14	**0.04**	0.13	**0.05**	0.13	**0.00**	0.06	**—0.01**	—0.01	**—0.07**
9	22.5	754.5	33	0.21	**0.12**	0.20	**0.10**	0.20	**0.10**	0.19	**0.11**	0.20	**0.08**	0.16	**0.09**	0.10	**0.05**
10	19.0	751.3	39	0.27	**0.17**	0.26	**0.14**	0.26	**0.15**	0.26	**0.17**	0.27	**0.14**	0.25	**0.15**	0.18	**0.11**
12	21.0	744.8	39	0.31	**0.19**	0.30	**0.15**	0.30	**0.17**	0.30	**0.19**	0.30	**0.15**	0.27	**0.16**	0.19	**0.11**
14	20.0	748.7	31	0.38	**0.23**	0.36	**0.19**	0.36	**0.20**	0.36	**0.23**	0.36	**0.18**	0.32	**0.19**	0.22	**0.11**
22	24.0	746.0	51	0.54	**0.32**	0.52	**0.25**	0.50	**0.27**	0.50	**0.29**	0.49	**0.23**	0.43	**0.25**	0.29	**0.13**
37	22.0	753.2	34	0.89	**0.55**	0.84	**0.46**	0 84	**0.48**	0.85	**0.53**	0.85	**0.44**	0.77	**0.47**	0.57	**0.29**
Diameter of Burettes in cm.				1.06	1.07	1.06	1.07	1.06	1.06	1.06	1.06	1 06	1.08	1.06	1.07	1.06	1.06

Conclusions. From the statements already made concerning the several variable factors involved in this work, one would predict certain of the results that are apparent in tables 1 and 2. The rate of evaporation should be greater in the 100 ml. burettes than in those of less capacity having a shorter radius of exposed surface; it should be less for water than for benzene which has, for a given temperature, a higher vapor tension; the vapor pressure of a solution 5N is less than that for one 0.25N, hence the rate should be less for the more concentrated solution; and covers over the ends of the burettes should decrease the rate, due to their partial closing of the systems and consequent prevention of freely circulating air from carrying away the gaseous molecules of the liquids.

On account of the rather complex situation prevailing in these experiments, with the several variable factors uncontrolled, it is not possible to point out the effect of each variation. It seems probable that the effects of changes in barometric pressure and relative humidity are relatively small as compared with that for changes in temperature. An inspection of the results in table 2 for the eighth and ninth days shows a small change of the former variables but a distinct increase in the readings of the burettes, even though a decrease in the temperature should have decreased the vapor tension of the water and thus have decreased the rate of evaporation. It seems evident that a change of temperature of the solutions produces a change of volume considerably larger than the change resulting from a change of vapor tension, and in the opposite direction.

It has already been stated that experiments conducted under the conditions prevailing during this work cannot give entirely satisfactory results, but they do furnish a general basis for predicting what may happen when such measurements are made in the usual laboratory. It is evident that caps on burettes do retard the rate of evaporation; but it is also evident that the total loss through evaporation for an aqueous solution is small at the end of a day, even in the open burettes, and one never takes such a length of time for the ordinary titration. Changes of temperature are liable to cause a much greater change in the volume of a standard solution.

THE USE OF SOLUTIONS OF INORGANIC SALTS AS PERMANENT COLOR STANDARDS.

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In the colorimetric determination of certain substances a common procedure consists in comparing, by means of a colorimeter or some other device suitable for the desired accuracy, a definite volume of a solution containing the unknown substance with various standard solutions containing definite amounts either of the constituent being determined, or of some other substance showing the same color as this constituent. When a match is found between the unknown and one of the standards, it is assumed that the amounts of the color-forming constitu-

ent in the two solutions are identical, if of the same composition, or equivalent to each other, if of different compositions. Where frequent determinations are to be made in this manner, it is very desirable to have permanent standards for either of the cases mentioned. Loss of time results if one must prepare a new set for each day or determination; and one's work is uncertain if the colors of the standards change or fade following some reaction affecting the color-forming constituent.

The synthetic organic chemist has supplied us with compounds of every desirable shade of color which might be useful in the preparation of such standards. Unfortunately, many of these compounds do not maintain their color indefinitely when in solution and exposed to the light. In some the color fades; in others the colored solute coagulates and settles out, leaving the solution clear.

In the effort to avoid the difficulty arising from such instability of color with organic substances, occasional work has been done for a number of years involving the use of solutions of inorganic salts. The purpose of the present paper is to review the information available regarding the color of solutions of inorganic substances, to note the requirements of a permanent color standard and the limitations of inorganic substances for such purposes, to mention some of the possible combinations for permanent standards, and to present a résumé of previous work upon the subject. Experimental work is under way relating to certain colorimetric standards but sufficient data is not yet available for any definite conclusions.

The Color of Inorganic Substances in Solution. Compared with the amount that has been written concerning the color of organic compounds, there is a relatively small amount available regarding the color of inorganic compounds. Particularly is this true both for the actual colors of the solutions of the compounds and also for the permanency of such colored solutions.

Recently Bichowsky[1] has discussed the color of inorganic compounds from the standpoint of electronic structure and valence of the atoms. The color exhibited by any compound is the result of its selective absorption of light, and only those substances are capable of such absorption which have an arrangement of electrons free to vibrate in the proper manner. He points out that compounds of invariant valence elements are colorless, due to their high electron stability and consequent absorption of light of short wave lengths—the ultraviolet. According to Bichowsky's table of valence colors for the elements of variable valence, the chief elements we may expect to show color (omitting the rare earth elements and the oxides and sulfides of the variable valence elements) are copper, gold, (silver), titanium, vanadium, chromium, molybdenum, tungsten, uranium, manganese, iron, cobalt, nickel, ruthenium, rhodium, palladium, osmium, iridium, and platinum.

In figure 1 is given Mellor's adaptation of the periodic table as arranged by Bayley, in which the atomic weights and the atomic numbers of the elements have been included. The elements of invariant valence (forming colorless compounds) have been indicated with a cross.

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[1] Jr. Am. Chem. Soc. *40*, 500 (1918).

Those forming compounds with pronounced colors are inclosed in the circles. It is of interest to note in connection with the latter series of elements that, (a) the most common ones have the consecutive atomic numbers 22 to 29; (b) two other series of consecutive numbers are included; (c) all the transition elements are included; and (d) those not in the transition groups are substantially the ones adjacent to them. Although there are some colored compounds of the elements not already mentioned, it is probable that few of them will prove of value for the preparation of colored solutions.

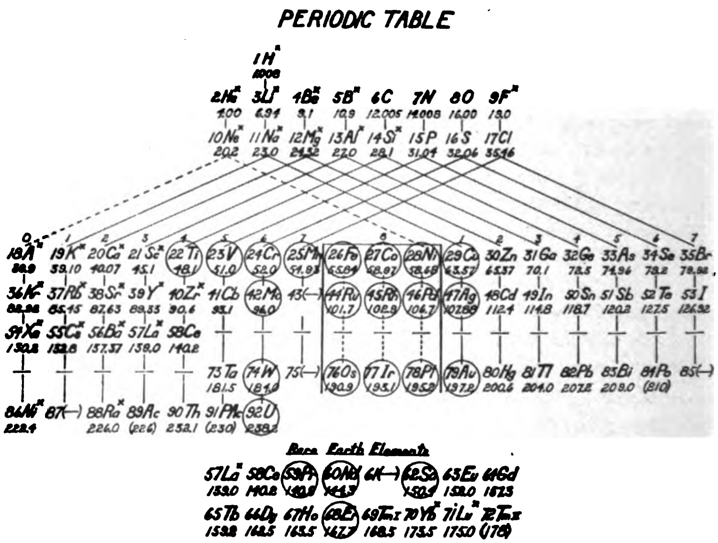

Fig. 1. Showing the location in the periodic table of the chief elements forming colored compounds.

Requirements of a Satisfactory Permanent Color Standard. Any solution to be considered as a possibility for a permanent color standard must first of all possess a color suitable for the purpose in hand, or be capable of giving it through proper blending. The color must be uniform throughout the solution and must not change in intensity or hue. To be suitable for general use the color must be such as to be accurately and readily reproducible. Furthermore, if two or more solutions are to be mixed in order to obtain some blend of the original colors, the solutes and solvents must be of such a nature that no reaction occurs on mixing which destroys the expected, resultant color. The intensity of the color must be sufficient—this requirement would practically eliminate the use of such compounds as manganous salts whose color in solution is very definite but relatively low in intensity. In general it is desirable to have dilution of a colored solution result merely in a decrease in intensity of the color rather than in a real change of color[2].

[2] Sheppard—Photo-Chemistry, p. 153, 159 (1914).

Limitations of Inorganic Compounds. When one attempts to select a set of solutions of inorganic materials whose colors include the seven primary, visible colors of the solar spectrum, he is at once confronted with an inherent scarcity of individual colors of a wide variety. The range is fairly well covered from the red of an aqueous solution of cobaltous chloride to the blue of an aqueous solution of cupric sulfate. These, however, do not include deep reds on the one end nor deep blues, indigos nor violets on the other. As will be noted later, deeper reds and blues may be obtained under certain conditions but the stability of the solutions has not been found entirely satisfactory. Some solutions have good colors but cannot be mixed with others, which makes their use limited.

While at certain times one may obtain a closely agreeing match between an unknown, colored solution and an inorganic permanent standard, at other times such a match may be difficult to accomplish, as in tests on such complex systems as the usual surface water. On the one hand, pure or mixed solutions show a clearness and brilliancy of color which many complex samples do not possess. On the other hand, the color produced in the solution to be tested may depend upon a variety of conditions, such as temperature, quantity of reagent added, manner of making reagent, variable quantity of accompanying substances, time elapsing after the preparation of the sample before comparison of the color, and others practically impossible to control closely. Uniformity in preparation and handling both of sample and standard are necessary in such cases.

Elevation of the temperature often changes the color of absorbing media[3]. It is well known, for example, that the red color of an aqueous solution of cobaltous chloride turns blue if the temperature is raised sufficiently. Another red solution, matching the color of the first but having a different composition, probably would not show the same change of color on passing through the same changes of temperature. When such a change of temperature causes a chemical modification, changes in the absorption spectrum occur; but in chemically stable systems, such as potassium bichromate, the alteration is small or nil.[4].

Another difficulty presents itself. It seems probable that, if one matched the green of a solution of nickelous sulfate with a green produced by blending solutions of cobaltous chloride, ferric chloride and cupric sulfate, the mechanism giving rise to the same color sensation in the two cases for one individual would not do so for another[5]. Arny[6] has found, for the conditions he studied, that several individuals obtained the same Lovibond readings on a number of different solutions; but Watson[7] states that the color sensation produced in different persons by the same quality of light may vary considerably.

Besides the effect of a change of temperature just mentioned, several

[3] Wood—Physical Optics, p. 441 (1911).
[4] Sheppard *Loc. cit.*, p. 163.
[5] Richards and Ellms Jr. Am. Chem. Soc. *18*, 75 (1896).
[6] Arny—Report 8th. Intr. Congr. Appl. Chem. *26*, 319 (1912).
[7] Watson—Textbook of Physics, p. 559 (1919).
Sheppard—*Loc. cit.* p. 150.

other factors may affect the permanency of the color of a solution. Among these may be mentioned the possibility of changing a color's hue or intensity, or both, through the reaction of the solvent and the solute, through the action of the solvent on the container, or through the action of light upon the solution. Many qualitative observations have been made bearing upon these reactions, but little data of a quantitative nature is available.

In discussing the photo-sensitiveness of salts of metals, Sheppard[6] states that "the greater proportion of ordinary crystallizable salts of the metals, whether in the solid state or dissolved, are comparatively stable in respect to light. But this stability is certainly relative rather than absolute, being an inverse function of the absorption of light of the bodies, and is, practically, not disconnected with the fact that it is rare for these bodies to be exposed without intermission. . . . It has been observed that aqueous solutions of the salts of the heavier, polyvalent metals undergo a gradual change of character on keeping. This change is apparently of the nature of a hydrolytic cleavage of the metal salt, leading by a series of reactions in stages, with concomitant side reactions fixing each stage enduringly and irreversibly as evolved, to the deposition of structurally conformed aggregates of insoluble oxides, sulfides, and ternary and quaternary complexes of varying composition."

Inorganic Substances Available for Colored Solutions. There are recorded many more or less isolated statements to the effect that various inorganic substances give a certain color in a given solvent, but no general summary or collection of such data has been found. Many of these colors, and particularly certain of those used as qualitative tests, are too transitory to merit consideration in this paper. Others are apparently permanent for a considerable period of time. The original intention was to present a list of those which seemed to offer the most promise of meeting the requirements already stated. The time available has proven too limited for the accomplishment of this compilation; but mention will be made of some of the types of substances which seem to have possibilities, even though their application may be limited. The solutions mentioned are at present being investigated. It is hoped that special apparatus will be available later so that quantitative data may be collected for them.

Aqueous solutions seem to be by far the most important. Those containing the color-forming elements mentioned in connection with the periodic table, in the form of simple cations, include our most familiar, colored solutions, such as cupric sulfate, ferric chloride, etc. The color of some of these solutions is markedly changed through the formation of complex cations under certain conditions, as the strongly ammoniacal solutions of cupric, cobaltic, and nickelous salts. It should be mentioned that pronounced changes of color of solutions of salts of some of the elements takes place on changing the solvent from 1 per cent hydrochloric acid to 30 per cent acid. The most common anions giving colored solutions are chromate, dichromate, permanganate, ferrocyanide, ferricyanide, and chloroplatinate.

[6] *Loc. cit.* p. 318.

Little can be stated at present regarding the colors of non-aqueous solutions of salts of the color-forming elements. In some cases there is a profound change in the color with the change from water as the solvent, as, for example, the change from the red of cobaltous chloride in aqueous solution to the deep blue with the salt dissolved in absolute ethyl alcohol. A solution of the same salt in acetone is a deeper red than an aqueous solution. A number of these solutions are being investigated.

A very limited class of solutions consists of those in which the elements as such are dissolved. A saturated, aqueous solution of bromine in water has a marked orange-red color. Iodine in carbon tetrachloride gives a beautiful pink colored solution, while in ethyl alcohol it shows a yellowish color. In certain other solvents these elements give somewhat different colors.

Certain colloidal systems consisting of a solid dispersed through a liquid show marked colors, such as the red of ferric hydroxide in water. It is distinctly questionable as to whether such a system would be of any value for permanent color standards.

Previous Work. An attempt has been made to collect the references relating to the use of solutions of inorganic salts as permanent color standards. The following résumé includes a statement of the principles and methods involved in the work for which reports have been located.

Crookes, Odling and Tidy[9] devised an instrument for comparing the colors of waters with solutions of inorganic salts. This instrument consisted of a pair of 24-inch tubes, one of which contained the water under examination, while the other remained empty. Behind the latter were placed two hollow wedges, one containing a 1 per cent solution of cupric sulfate, the other a solution of ferric and cobaltous chlorides containing 0.7g. of iron and 0.3g. of cobalt per liter, with a slight excess of free hydrochloric acid. These wedges were pushed over the empty tube until their color matched that of the water under examination in the other tube, and the color was recorded as equal to so many millimeters of blue and red solutions.

Hazen[10] proposed the use of a mixture of potassium chloroplatinate and cobalt chloride as a color standard for natural waters. The stock solution contained 1.246g. of potassium chloroplatinate (0.5g. Pt) and 1g. of crystallized cobaltous chloride (0.25g. Co) and 100ml. of concentrated hydrochloric acid, the whole being diluted to one liter. Solutions for comparison were made by diluting 1, 2, 3, . .ml. to 50. This solution was found to be unaltered after one year, even when standing in the light.

Jackson[11] reported the use of permanent color standards for the colorimetric determination of several constituents in water. The various standards used consisted of mixtures of solutions of the following salts:

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[9] Chem. N. *43*, 174 (1881).

[10] Am. Chem. Jr. *14*, 300 (1892).
A.P.H.A. Standard Methods of Water Analysis, p. 9 (1917).

[11] Tech. Quar. *13*, 314 (1900).
A.P.H.A.—*Loc. cit.* p. 17 (1917).

for ammonia, potassium chloroplatinate (2g. per L.) and cobaltous chloride hexahydrate (12g. per L); for nitrites, cobaltous chloride hexahydrate (24g. per L.) and cupric chloride dihydrate (12g. per L.); and for iron, cobaltous chloride hexahydrate (24g. per L.) and potassium chloroplatinate (12g. per L.). In the preparation of each solution the salt was dissolved in water, 100ml. of concentrated hydrochloric acid added, and the whole diluted to one liter.

Kendall and Richards[12] discussed the factors preventing a perfect match between permanent color standards and the colors obtained with many samples of water. As standards for routine work they do recommend the use of a neutral solution of potassium chromate in connection with the Grandval and Lajoux test for nitrates, and of various dilutions of Tidy's formula (0.25g. potassium dichromate and 9.05g. cobaltous sulfate heptahydrate per L.) for the determination of ammonia.

Washburn[13], by combining "in the proper proportions" solutions of ferric chloride, cobaltous nitrate and cupric sulfate, prepared permanent color standards for use in determining the proper iodometric end point in the determination of arsenious acid.

McBain[14], in his study on the use of phenolphthalein as an indicator, employed as permanent standards solutions containing mixtures of copper and cobalt salts, acidified with nitric acid to prevent hydrolysis. The most dilute solution contained 0.50g. cobalt nitrate hexahydrate and 0.62g. cupric sulfate pentahydrate per liter; the others contained 2, 3, etc., times these amounts. The difference between any two standards was planned to be equivalent to the color change caused by the addition of one drop of N/250 acid or base.

Arny[15], following Washburn's suggestion for blending solutions colored by the cobaltous, ferric and cupric ion, proposed the adoption of solutions containing these ions as "international standards for colored fluids". By mixing these three primary colors, red, yellow and blue, in the proper proportions he obtained 88 blends, ranging from the red through to the blue. These solutions are designated as the "Co-Fe-Cu" standards. In the preparation of the standards, 0.5 N solutions were made of cobaltous chloride, ferric chloride and cupric sulfate by dissolving the salts in 1 per cent hydrochloric acid. All of the work was checked by means of a Lovibond tintometer, and the acidified solutions were found to give the same readings after standing for a year.

Arny and Pickhardt[16] discussed the requirements of satisfactory color standards and reported further observations on the "Co-Fe-Cu" series proposed earlier. This series lacks deep reds and deep blues.

Arny and Ring[17], in the effort to provide for the deficiencies of the "Co-Fe-Cu" series, proposed a new series of 0.1 N ammoniacal solutions of chloropentammine cobaltic chloride (red), ammonium chromate (yel-

[12] Tech. Quar. *17*, 277 (1904).
[13] Jr. Am. Chem. Soc. *30*, 31 (1908).
[14] Jr. Chem. Soc. *101*, 814 (1912).
[15] Report 8th Intr. Congr. Appl. Chem. *26*, 319 (1912).
Jr. Am. Pharm. Assoc. *2*, 76 (1913).
[16] Druggist's Circular *58*, 131 (1914).
[17] Jr. Franklin Inst. *180*, 199 (1915).

low) and ammonio-cupric sulfate (blue)[18]. When mixed in various proportions, these salts were found to produce all hues except a few delicate pinks and violets. The tints which could not be produced by this "Co-Cro-Cu" series were obtained by means of mixtures of 0.001 N potassium permanganate and 0.01 N potassium dichromate, known as the "Cro-Mn" series. In the "Co-Cro-Cu" series the red and yellow solutions were found to remain unchanged in color if kept well stoppered. The blue solution, however, precipitates within a few weeks and must be prepared frequently. In the "Cro-Mn" series each solution is stable alone, but they begin changing an hour after mixing.

Arny and Ring[19] reported further use of the above mentioned solutions in connection with certain pharmaceutical work.

Arny and Ring[20] reported the application of the three series of solutions in the preparation of permanent standards for use in the colorimetric determination of ammonia, nitrates, nitrites, vanillin, uric acid, salicylic acid and phosphates. They state that practically every tint desired in colorimetric work can be obtained with the three series of colors. The original acidified "Co-Fe-Cu" solutions and their blends neither fade nor precipitate until at least two years old; the ammoniacal cobalt and chromate solutions show no fading after a year. The ammoniacal copper solution precipitates and undergoes change of color within a few weeks, but the blends keep satisfactorily when sealed in ampules or kept in well filled, rubber stoppered bottles which are not opened. The concentration recommended in this paper for the "Co-Cro-Cu" series is 0.02 N.

Arny, Kish and Newmark[21] discussed the unreliability of the Lovibond tintometer for the testing of cottonseed oil, and proposed the use of the "Co-Fe-Cu" and "Co-Cro-Cu" color standards.

Kolthoff[22] was the first to propose the use of permanent color standards instead of the usual buffer solutions and indicators in the colorimetric determination of hydrogen ion concentration. By means of M/4 cobaltous nitrate and M/6 ferric chloride he prepared solutions which match the colors of buffer solutions through the pH range of certain indicators. Matches were made showing the change in color of neutral red, methyl orange, tropaolin 00 and partially for methyl red.

Snell[23] recommends the use of Arny's "Co-Fe-Cu" series for the preparation of permanent standards for the colorimetric determination of carbon, lead, chlorine, and possibly for aluminium. He states further, that for the determination of bismuth, permanent standards may be made using the same reagents as in the case of the unknown sample. Solutions of potassium chromate, potassium chloroplatinate and ammoniacal cupric chloride may be used for permanent standards for the determination of chromium, potassium, and oxygen, respectively.

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[18] Note—Salts of copper and cobalt are M/20 and the dichromate M/120.

[19] Jr. Am. Pharm. Assoc. *4*, 1294 (1915).

[20] Jr. Ind. Eng. Chem. *8*, 309 (1916).

[21] *Ibid.* *11*, 950 (1919).

[22] Pharm. Weekblad *59*, 104 (1922).

[23] Colorimetric Analysis (1921).

AN IMPROVED MUREXIDE TEST FOR TEACHING PURPOSES.

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During my class work in chemistry in medical college I directed my students to follow Hoffmann and Ultzmann as a laboratory guide. Directions for the murexide test were as follows: Mix concretion in a small mortar, place in a porcelain dish, add a few drops of nitric acid and a little water and warm carefully over a flame until the uric acid is dissolved. Evaporate cautiously, almost to dryness. Already we notice during the evaporation, if uric acid is present, onion-red streaks on the walls of the dish which vanish suddenly if that portion of the dish approaches the flame. If, when the fluid has evaporated to dryness, we add a drop of ammonia to the residue the whole interior of the dish becomes a beautiful purple-red (murexide acid-purpurate of ammonia). If KOH is added to the residue it becomes violet-blue. The murexide depends upon the fact that by the addition of HNO_3 and heat, first alloxan and then alloxantine is formed which on addition becomes murexide.

It is very commonplace for 50 per cent of the class to make failures. It seems difficult for them to gauge the proper amount of dilution and the requisite amount of heat. I adopted the following method without more than two per cent of failures.

Heat the concretion slowly in an evaporation dish with a minimum amount of water acidulated with nitric acid until the approach of dryness. Put metal plate over low flame burner frame and upon it a moistened salt of ammonium; then invert the evaporating dish over the ammonium so that the fumes are confined. This operation is quickly accomplished and there is little opportunity for error and too, even a student who is a novice, will not fail in this method of demonstration.

"Proc. 38th Meeting, 1922 (1923)."

FOG FORMATION IN AIR WHICH HAS PASSED THROUGH A SILENT DISCHARGE.

BY F. O. ANDEREGG and K. B. MCEACHRON, Purdue University.

The corona discharge has been studied in the Chemical Laboratory[1],[2] and Electrical Engineering Experiment Station[3],[4] of Purdue University with especial reference to the formation of nitric acid and ozone in air. One of the more interesting of the phenomena observed while working under a large variety of conditions has been the formation of fog in the air passed first through a discharge and then through a solution for the absorption of the nitric acid anhydride or the ozone formed in the discharge. An important connection between fog formation and the yield of nitric acid was suspected. This led to a study of fog formation in the corona work during a period of several years, the results of which are recorded here.

A fog, in the first place, may be defined as the suspension of finely divided particles of liquid, (or frozen liquid if the temperature is low enough), in a gas. In order to have a fog there must be moisture in the atmosphere, usually approaching the saturation point. There must be also nuclei on which the fog may be condensed because it has been shown that in the absence of all nuclei a large supersaturation is required to condense the water[5]. Nuclei may be dust particles, ions[5] or chemical substances of a hygroscopic character[6]. The absence of dust particles sufficient to cause formation under the conditions used is shown by the fact that during the sweeping out of the apparatus preliminary to discharge no fog was observed at any time. Ions did not serve as nuclei for the following reasons: C. T. R. Wilson[5] shows that a certain amount of supersaturation is necessary before water vapor will condense on ions. Passing the air coming out of the discharge tube through a large electrostatic field failed to have any effect on the fog either before or after the discharge was turned on.

There remain as nuclei only hygroscopic compounds. That it was due to the chemical substances was proved by dividing the stream of air after leaving the discharge. One-half passed directly into the absorption system and fog was observed as usual. The remainder of the gas passed through a large tube containing asbestos impregnated with silver so that the ozone was decomposed completely and the nitrogen pentoxide reacted with the silver oxide so formed to produce silver nitrate[6]. The air then passed through an absorption apparatus and gave no evidence of either ozone or oxides of nitrogen or fog. Ozone alone in contact with moisture has a slight tendency to produce ioniza-

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[1] Anderegg. J. Am. Chem. Soc. 39, 2581 (1917).
[2] Ray and Anderegg. *Ibid.* 43, 967 (1921).
[3] Harding and McEachron. J. Am. Inst. Elec. Eng. April, 1920.
[4] McEachron and George. Purdue Univ. Eng. Exp. Sta. Bull. 9.
[5] C. T. R. Wilson. Phil. Trans. 189A, 265 (1897) ; 193A, 289 (1899).
[6] Bancroft. J. Phys. Chem. 22, 312 (1918).

tion and to cause fog formation[7]. In working with pure oxygen it is possible to secure conditions such that a slight fog is produced on ab-

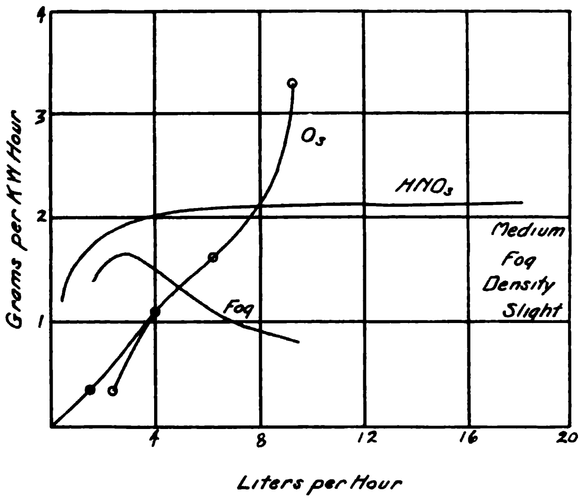

Fig. 1. Formation of nitric acid, ozone and fog in air at 460mm. pressure in a very large discharge apparatus at more than 50,000 volts. The nitric acid curve is given as figure 8 by Harding and McEachron, cit. 3. The other curves have not been published.

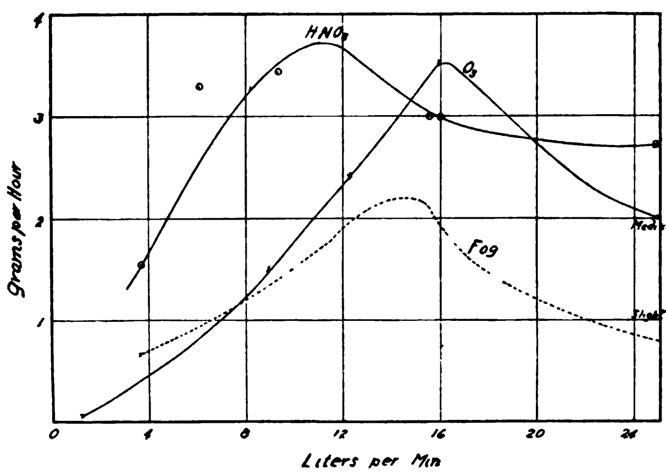

Fig. 2. The same tube was used as in figure 1, but the pressure of the air was 560mm.; cf. figure 9, cit. 3.

sorbing the ozone in potassium iodide solution. But the fog produced by the ozone alone was a very small part of the total observed. That leaves the nitrogen pentoxide which is, like sulfur trioxide, a very hygro-

[7] Pringal. Ann. Physik. 26, 727 (1908). Pringal's explanation is obviously wrong because ozone will not react with unactivated nitrogen, cf. Bieber. ibid. 39, 1313 (1912).

scopic substance. Its ability to condense moisture is indicated by the titration of the fog collected from a small Cottrell precipitator. The acid so obtained had a concentration approximately normal.

Nitric oxide (NO) is first formed in the discharge. This combines quantitatively with the ozone which is also present[8] unless the temperature is too high, to give the nitrogen pentoxide. According to this reasoning those conditions which give the maximum product of the concentrations of ozone and of nitrogen pentoxide should produce the most fog. The curves given, figures 1, 2 and 3, which are typical of a very

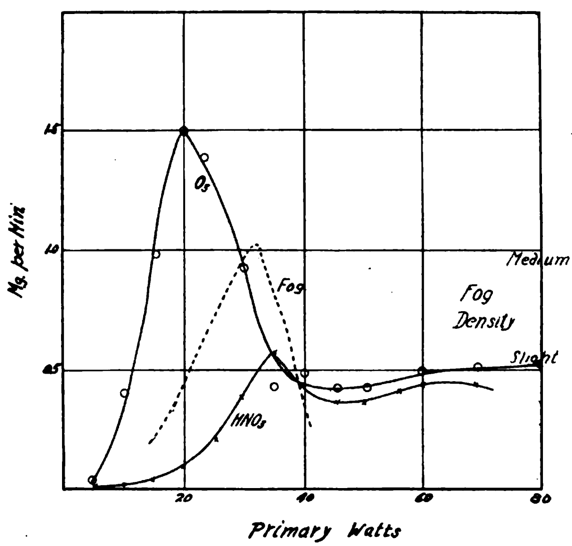

Fig. 3. The formation of ozone, nitric acid and fog in air which was undergone discharge in contact with fragments of quartz glass; cf. Anderegg and Bowers, A Type of Silent Discharge Involving Catalysis, page 177.

large number of similar curves, indicate the validity of this reasoning.

It was observed that the fog developed to a maximum during the course of a run and then gradually diminished in strength at a rate which depended upon the flow rate of the air. The cause for this was the cooling effect of the evaporation of moisture into the air reduced the temperature sufficiently to lower the amount of moisture evaporated below the condensation point.

The reason for the passage of these fume particles has been explained by Bancroft[9] as due to the adsorption of a layer of air on the surface which acts like a cushion to prevent the droplet of nitric acid solution from coming in contact with the alkaline absorbing liquid.

[8] Wulf, Daniels and Karrer. J. Am. Chem. Soc. 44, 2402 (1922).

[9] Bancroft. Applied Colloid Chemistry, pp. 65-78 (1921).

AN OSCILLOGRAPHIC STUDY OF AN INDUCTION COIL WITH HIGH FREQUENCY LOAD.

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A report was made to this Academy a year ago on a Chemical Study of a High Frequency Corona Discharge[1]. During the preliminary work a large induction coil capable of throwing a 40 cm. spark was connected to the Tesla coil as described in that reference. The source

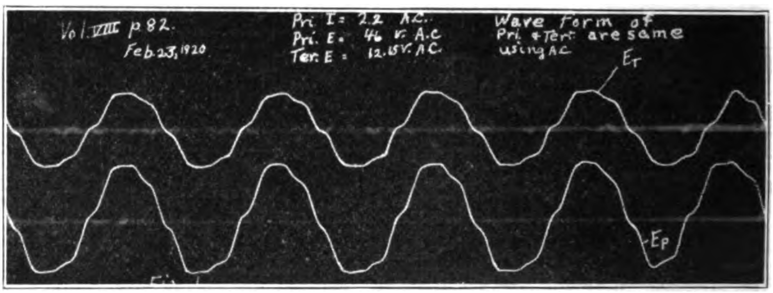

Fig. 1. An oscillograph showing that the wave form of the voltage from a tertiary coil wound outside of the secondary coil of an induction coil is the same as the alternating voltage impressed upon the primary coil, all three coils being concentric.

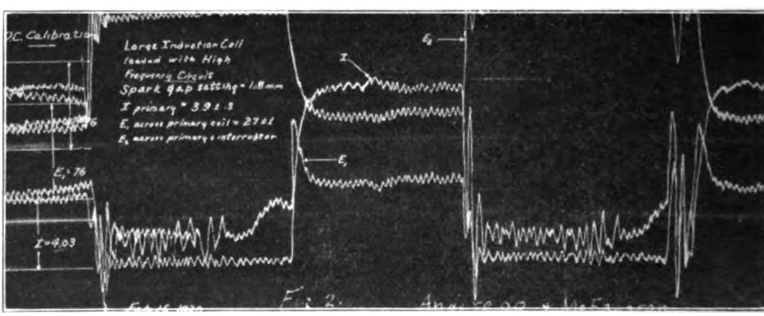

Fig. 2. The wave forms of the current and voltages of the primary circuit of a large induction coil. The current was supplied by an 8-pole d.c. generator, explaining the small waves.

of supply for the primary of the induction coil, was the campus direct current at 100 v. The yields of ozone obtained with this arrangement were very unsatisfactory as to consistency of results. Later, a transformer was used in place of the induction coil with much better results. A General Electric oscillographic apparatus being available, a study was made of the induction coil to see if the variations could be explained.

The secondary current could be obtained directly with the aid of a sensitive element. To get the secondary voltage a tertiary coil was

[1] Proc. Ind. Acad. Science, 1921, p. 157.

"Proc. 38th Meeting, 1922 (1923)."

wound around the outside of the secondary and the ratio between the secondary and tertiary was determined with a standard spark gap. The ratio was 440:1. Figure 1 shows an oscillograph of the primary and tertiary voltage waves and it is seen that the two forms are identical as would be expected, when it is remembered that the winding in the induction coil consists of a primary coil wound on the magnetic core

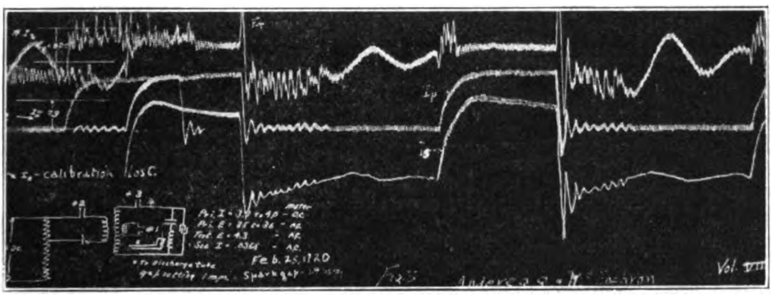

Fig. 3. The induction coil was loaded with a high frequency discharge. The peculiar character of the tertiary voltage wave is noteworthy. Note the considerable part of the wave below the zero line indicating reversal of voltage.

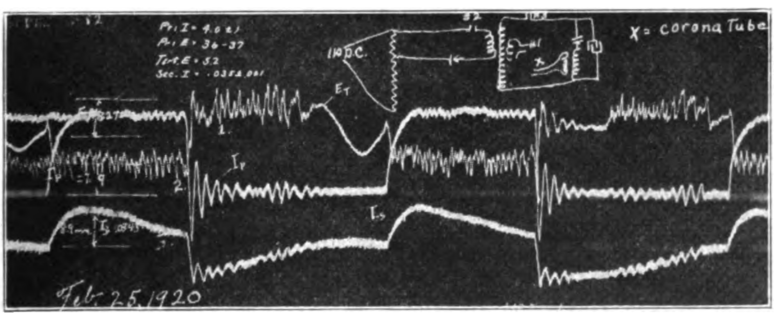

Fig. 4. Same as figure 3. Note the alternating character of the secondary current and of the tertiary voltage. These oscillographs indicate the marked deviation from unidirectional current usually associated with the induction coil.

around which is the secondary and finally the tertiary is wound outside of that.

The other figures, 2, 3, and 4, are self-explanatory. The voltage and current waves are far from being even uni-directional. Attention is called to the peculiarities of the tertiary voltage wave. From the oscillographs it is not to be wondered that the chemical effects, which are so sensitive to small voltage charges, are so inconsistent.

A TYPE OF SILENT DISCHARGE INVOLVING CATALYSIS.

F. O. ANDEREGG and E. H. BOWERS, Purdue University.

The complications occurring at the solid surfaces in contact with electrical discharges are not generally appreciated. As a result of considerable study of chemical reactions in corona discharges the fact that the solid-gas interface introduces variable factors has become more and more evident. From a knowledge of the phenomena involved in contact catalysis it has become increasingly clear that these two apparently unrelated phenomena may be interdependent. The result of this dawning consciousness has led to a study of catalysis in chemical reactions in corona discharges, the first report of which is given here.

The theory of the action of a dielectric material in an electric field was first given by Faraday[1], who showed that the attraction between charged bodies is inversely proportional to the dielectric constant of the

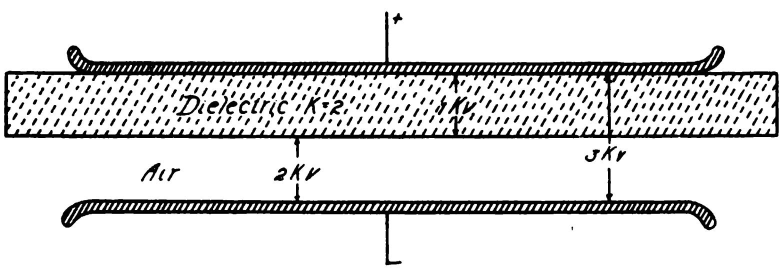

Fig. 1. The interposition of a dielectric material of constant 2 has increased the potential drop in the remaining air space from 1.5 to 2 Kv.

material separating them. Then, when equipotential lines are drawn (normal, of course, to the lines of force), they will be spaced in proportion to the dielectric constant of the material used. The term, specific inductive capacity, is more illustrative of the effect but its length militates against its use. If sheets of dielectric material, such as glass, are placed against one or both of parallel electrodes without filling the whole space between them, there will be a distribution of equipotential lines as given in figure 1. The equipotential lines are close together in the gas filled space so that there is a large potential gradient in the gas. It may be helpful to remember the analogy to contour lines on a map. If the potential is sufficient the gas "breaks down", that is, some of the molecules are ionized and a silent or corona discharge is set up. The presence of solid dielectric *tends* to prevent sparking or arcing over, so that with a suitably designed apparatus it is possible to fill the whole of the space with a corona of high density. If a rod of glass or other dielectric material is placed between parallel electrodes the effect of the lines of force is as given in figure 2[2]. On placing two

[1] Jeans. Electricity and Magnetism. 4th Ed. pp. 126-135 (1920).
[2] Jeans, loc. cit., p. 228.

rods in contact it is seen (figure 3) that the space of closest contact is one of high potential gradient. This device of using glass rods in an electric field has been tried out at Purdue by K. B. McEachron[3], who has obtained some high yields of ozone.

Similar reasoning would show that a sheet of dielectric material between two parallel electrodes would produce no distortion of the field. This theory has been tested experimentally by C. W. Rice[4] using glass cylinders with experimental conditions such that there were no "end effects". It was found that the presence of the cylinder always lowered the arc-over voltage. The condition of the surface and especially the nature of the gas or vapor adsorbed on it were found to have important effects. Moisture is always very potent in aiding the arc-over[5]. These observations led to the idea that the mechanism of this promotion of arc-over was catalytic in nature. Just as solid surfaces promote chemical reactivity by adsorbing the reacting substances and activating them by loosening their bonds so here the adsorbed molecules

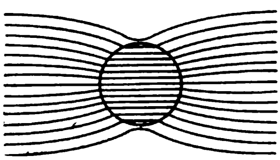

Fig. 2. The lines of force in an electric field are distorted by a rod or sphere of dielectric material.

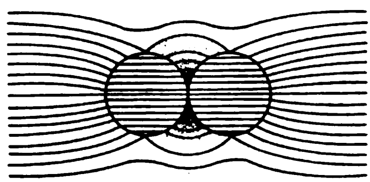

Fig. 3. Two such bodies in contact distort the lines of force as shown. The maximum discharge in the gas occurs in the shaded areas.

in an activated condition would be much more easily ionized and would aid materially in establishing a path of discharge[6].

For this catalytic action of promoting creepage along the surface the name, "creepage corona" is proposed. In any discharge involving dielectrics there will be two effects, that of the specific inductive capacity in increasing the discharge density and the creepage action in increasing the discharge current. In addition, the purely catalytic effect on any chemical reactions of the solid-gas interfaces will produce effects which

[3] McEachron and George. Purdue Univ. Eng. Exp. Sta. Bul. No. 9. pp. 58-108 (1922).

[4] C. W. Rice. Trans. Am. Inst. Elec. Eng. 36, 1947 (1917).

[5] This action of moisture is due to the polarity of the water molecule. Replacing the polar water with nonpolar oil lowers the creepage effect and raises the arc-over potential.

[6] G. V. Hevesy. Z. Physik. *10*, 80-3 (1922), who found that small crystalline conglamerates had fifty times the conductivity of large crystals, explains the results as due to "loosened spots" in the crystal lattice which would result in an irregularity in the order of the ions especially at the surfaces. H. S. Taylor. Chem. Age. *30*, 309; J. Franklin Inst. *194*, 1 (1922), explains the catalytic action of reduced copper on the reduction of copper oxide at the point of contact of the two phases, as due to a distortion of the adsorbed reducing gas when in contact with the different electronic configurations in the two phases.

superimposed on the other, are apt to be rather too complicated for theoretical treatment. The conclusion that the effects are in large part catalytic, is seen to be justified from the following experiments.

EXPERIMENTAL. A Liebig condenser forms a convenient laboratory apparatus for testing the effects of different dielectric materials upon various combinations of gases. The outer jacket with its cooling water running through serves as one electrode and it is convenient to use an aluminum wire at the axis of the tube for the other electrode. Aluminum is covered with a very coherent coating of oxide which decreases its catalytic activity, apparently as far as the corona discharge is concerned. A small experimental transformer with the ratio of 120:1 was used and the connections are given in figure 4. The power actually supplied to the tube has not been determined in these first experiments. The secondary voltage was simply obtained from the transformer ratio

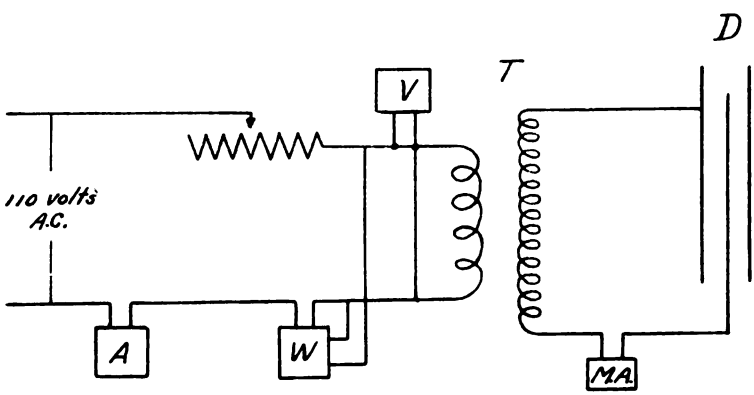

Fig. 4. Diagram of connections.

and the reading of the voltmeter. Air, carbon monoxide and mixtures thereof freed from carbon dioxide and moisture have been studied. The arrangement of the apparatus is indicated in figure 5.

The dielectric materials experimented with have included fragments of ordinary glass rods, of quartz glass, of earthenware (clay marbles) with and without impregnation with beeswax. Crystalline hematite, as well as white and blue flint were also used in addition to glass wool. Some experiments were made with no fragments of dielectric material around the inner wire electrode. The actual density of the space when packed with glass fragments was twice that when packed with glass wool. The surface of the glass wool, was however immensely the greater, resulting in enhanced chemical effects.

Some of the curves obtained for ozone formation[7] in air are given in figure 6 while figure 7 gives similar results for nitric acid yields. Figure 8 gives typical curves for the simultaneous production of both ozone and nitric acid in contact with white flint. With the increase in

[7] Proc. Ind. Acad. Sci. 1921, p. 159, for details of analysis.

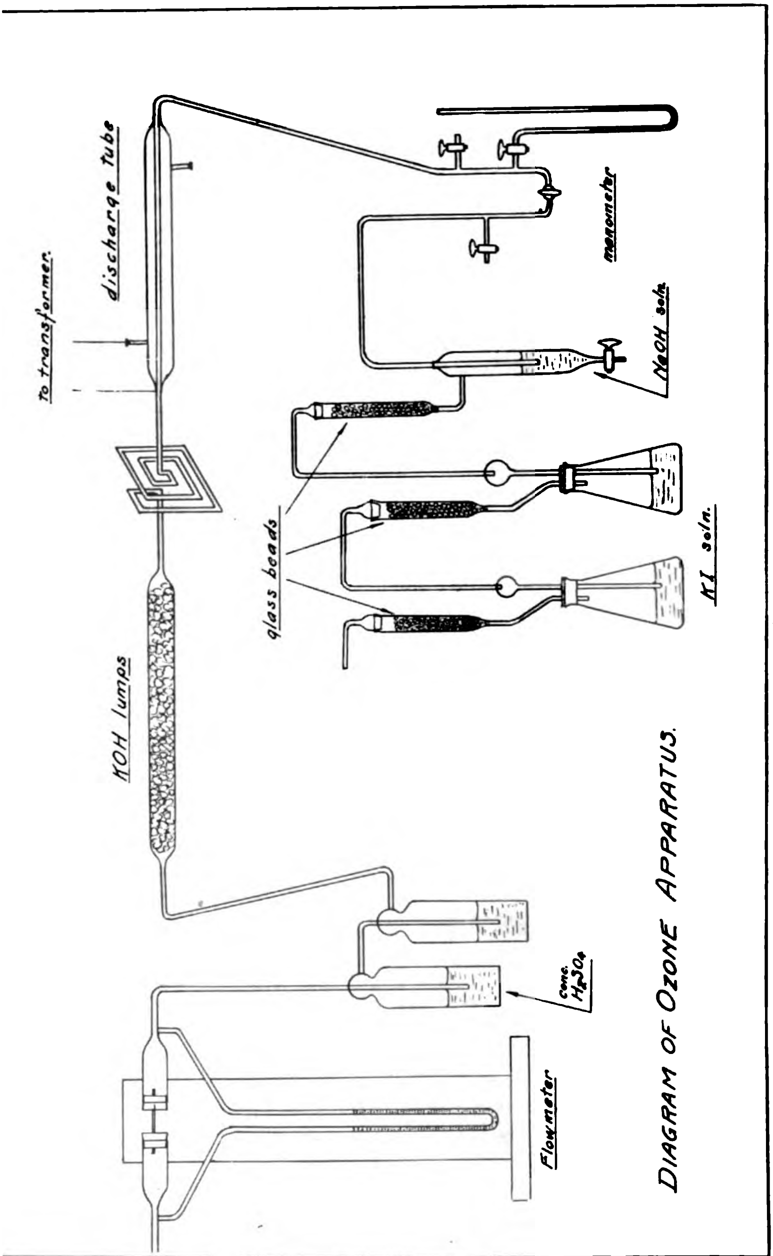

Fig. 5. Diagram of ozone apparatus.

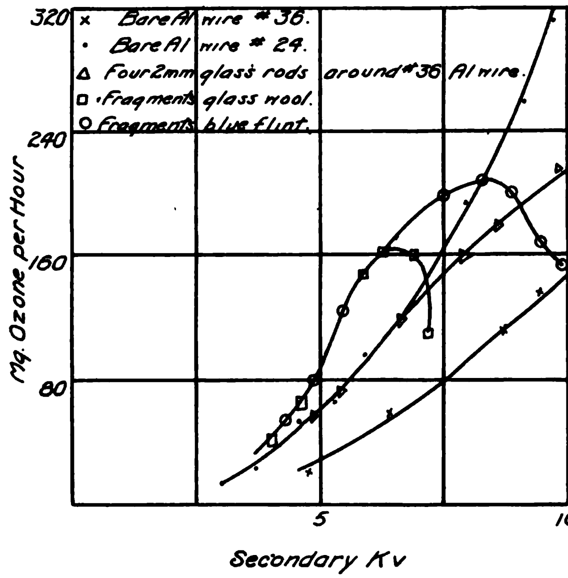

Fig. 6. Ozone formation with and without fragments of dielectric material in contact with the discharge.

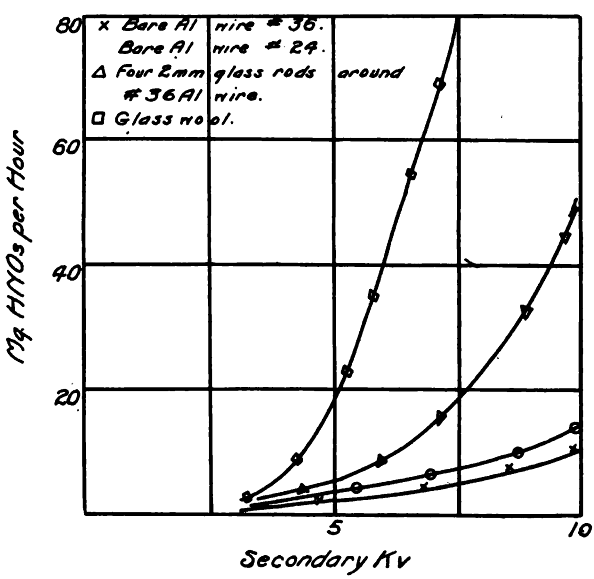

Fig. 7. Nitric acid formation with and without fragments of dielectric material in contact with the discharge.

the intensity of the discharge the amount of nitrogen activated increases. The ozone or ozone forming activated oxygen is used up to combine with this nitrogen and then to further oxidize to nitrogen pentoxide. Incidentally, with the increase in the intensity there is more local heating and catalytic decomposition of ozone. These sometimes have, with rising voltage, a periodic increasing and decreasing in which the opposite slopes of the ozone and nitric acid curves are the noteworthy feature. Blue flint has been found to be the best material for the production of ozone except at very high voltages when no dielectric material is desirable. Glass wool is much more effective than glass rods for the oxidation of nitrogen.

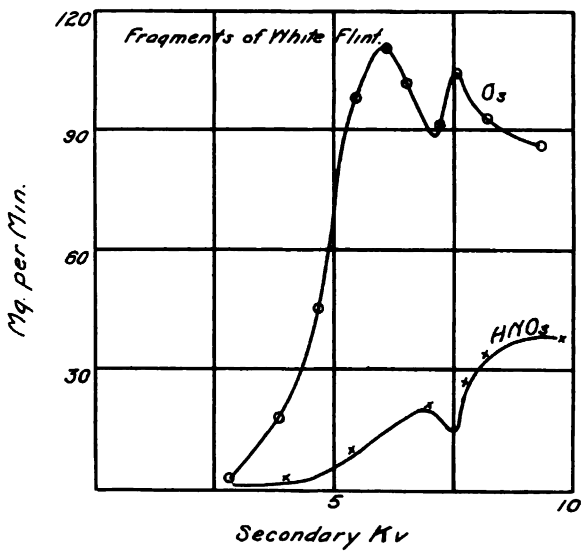

Fig. 8. Ozone and nitric acid formation in contact with fragments of white flint. Note the depressing action of the higher yields of nitric acid on ozone formation.

The curves for the decomposition of carbon monoxide are remarkably similar in shape to the curves for nitric acid production and so have not been given. The color of the discharge in carbon monoxide is worthy of remark. It is a pale light green, sometimes with a bluish tinge. With increase in air content it shifts over into the characteristic purple of resonant nitrogen. A tube which had been subject to discharge for some time was suspected to have carbon deposited on the fibers of the dielectric, glass wool. On letting in air and continuing the discharge some beautiful scintillations were observed. Little threads of fire would creep along the fibers and branch out to connecting fibers in a spectacular fashion. The notable differences in the results with different dielectric materials are due to catalytic action at the surfaces.

A FURTHER STUDY OF PRESSURE REVERSALS IN THE CORONA DISCHARGE.

F. O. ANDEREGG, Purdue University.

Last year K. B. McEachron presented a paper before this Academy, entitled, "Some Characteristics of a Siemens Ozonizer,"[1] in which a number of experiments with a corona discharge in stagnant air were described. Some very peculiar results were obtained which are not well understood. Further work seemed desirable and an account is given here of some experiments which have been made under somewhat dif-

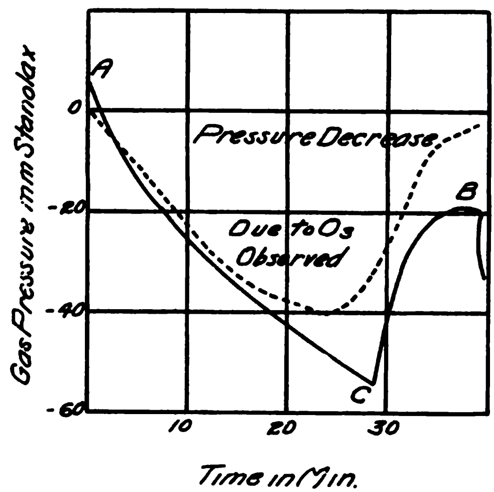

Fig. 1. There is usually an initial jump in the pressure on turning on the discharge due to the ionization pressure (Kunz). At C there is a reversal in pressure which is rather abrupt. When the current is turned off at B there is a sudden decrease in pressure due to the removal of the forces which produce the ionization pressure.

ferent experimental conditions. New facts are added to our knowledge of reversals and the foundation is being laid for an adequate explanation of these peculiar effects. It seems almost certain that the effects are catalytic in nature but the mechanism needs further elucidation.

Experimental: A No. 36 aluminum wire was placed at the axis of a Liebig condenser and was surrounded by four glass rods each two mm. in diameter. From the dielectric constant of the glass it is possible to calculate their dielectric effect on the discharge (Cf. preceding article). Air, dried and freed from carbon dioxide, was enclosed within the tube and the discharge was allowed to pass under definite conditions. The method of making analysis of the gases for ozone and oxides of nitrogen has been described.[2] A small transformer was used to step

[1] McEachron. Proc. Ind. Acad. Sci. 1921, p. 171.
[2] Anderegg. Proc. Ind. Acad. Sci. 1921, p. 159.

up 110 V. alternating current. The voltage was taken from the primary voltmeter reading and the transformer ratio. The gas pressure in the tube was measured by means of a manometer filled with "stanolax", a heavy paraffin oil with a density of 0.857. Some of the results obtained are given in figure 1. It is to be noted that there is a critical voltage above which there is no pressure decrease under the given conditions. At the lower voltages the first part of the decrease in pressure, when allowance is made for the ionization pressure[3] is exactly caused by the ozone formed as is shown in figure 2. Towards the re-

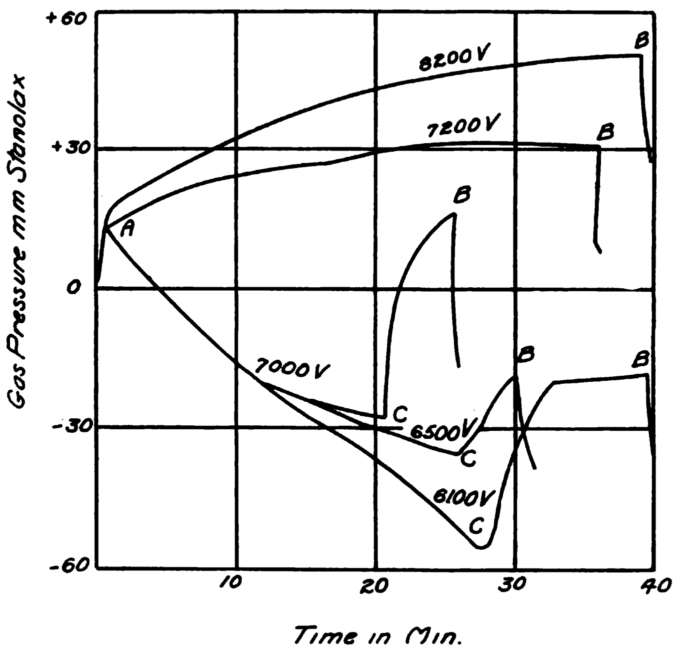

Fig. 2. A series of runs over varying length of discharge time was made at about 6100 volts.

versal point there is an accumulation of oxides of nitrogen which prevent the further formation of much ozone. This part checks McEachron's results.

Discussion. In the corona discharge ozone is the chief product formed at first, provided the intensity of the discharge and the temperature are not too great. A little nitrogen is oxidized, which gradually accumulates with time, and not only reduces the ozone concentration, but prevents further ozone formation. There are two possibilities, one is catalytic decomposition of the ozone molecules in the gas space by oxides of nitrogen; another is the adsorption of the oxides of nitrogen, (these may possibly be very heavy molecules), on the walls

[3] Kunz. Phys. Rev. 8, 285 (1916) ; 10, 483 (1917) ; 19, 165, 244, 390 (1922).

of the tube where the ozone may be catalytically decomposed. In addition the accumulation of oxides of nitrogen on the walls will change the nature of the surface and therefore the nature of the discharge is apt to be altered. The discharge tends to be concentrated into a few brushes in which the more intense activation allows less and less ozone to exist. Finally, when the whole wall is all covered a further change in the discharge occurs. The adsorbed molecules are more or less driven off and decomposed, explaining the pressure increase. There is, doubtless, a very complicated state of affairs. This hypothesis gives an explanation of the observed facts. It is now being further tested experimentally.

IMPROVED DESIGNS OF SOUND CONDENSERS.

ARTHUR L. FOLEY, Indiana University.

The writer has shown in former papers that a number of the generally accepted theories in regard to the passage of sound through tubes[1] and the action of horns[2] are not tenable. The theory that when a horn is used as a sound "condenser" all or even the greater part of the energy entering the large end is condensed at the small end is far from the truth. Sound waves do not pass through a horn, like shot or water poured into a funnel. The energy condensed at the small end of a conical or flared horn is not even approximately equal to that entering the large end. If the horn is one of large angle, the condensed energy is usually but a small fraction of the entering energy. The major part of the entering energy is lost by reflection; it backs out of the horn at the end it entered.

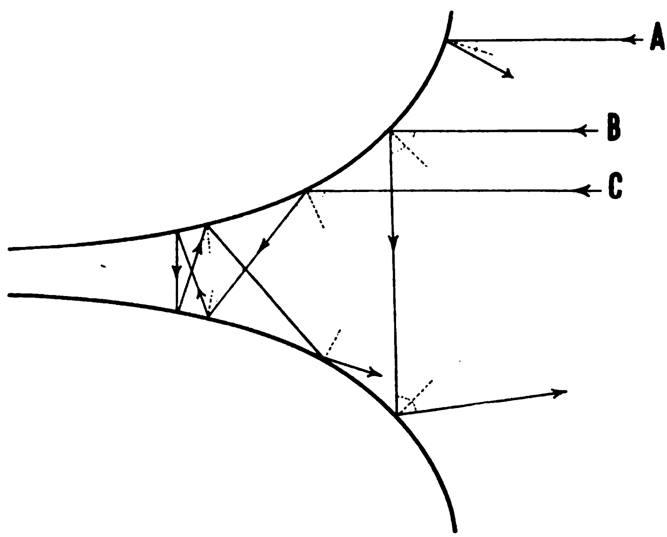

Fig. 1. Cross section of flared horn, showing how wave energy is reflected backward and out of the large end.

Owing to the fact that sound waves are long, compared to light waves, one can not—using sound reflecting surfaces of usual size, expect close agreement between optical and acoustical phenomena. Sound diffraction is a most disturbing factor. However, there is no reason why Huygen's theory should not be applied to determine the direction

[1] The Speed of Sound Pulses in Pipes. Phys. Rev., N.S., Vol. XIV., No. 2, Aug., 1919.

The Velocity of Sound Waves in Tubes. Proc. Ind. Acad. Sci., 1919.

[2] A Photographic Study of Sound Pulses Between Curved Walls and Sound Amplification by Horns. Phys. Rev., S.S., Vol. XX, No. 6, Dec., 1922.

"Proc. 38th Meeting, 1922 (1923)."

of the main portion of a reflected sound wave. For this portion of wave the law that the angle of incidence equals the angle of reflection is as true as it is in the case of light. The writer has proved this statement in the case of sound pulses from electric sparks, by photographing such waves in various stages of reflection from surfaces of several different shapes.

Let us apply the law to the case of a plane sound wave entering the large end of a flared horn, as in figure 1. The portion of the wave which is lettered A is reflected back and out at the end it entered, after but a single reflection. The portion lettered B backs out after two reflections, while C does so after six reflections. Reference to the photographs published in the author's papers referred to above, shows clearly and conclusively that this is exactly what happens. The data therein

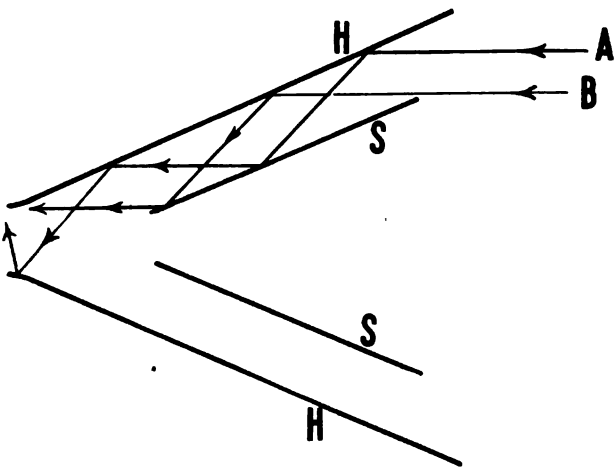

Fig. 2. Cross section of a multiple conical horn, showing how wave energy may be reflected to the small end of the horn, resulting in increased amplification.

published shows that a horn of wide angle "condenses" very little more energy than one of small angle.

Suppose now that we take an ordinary conical horn H, shown in cross section in figure 2, and place within it and coaxial with it a similar but smaller horn S. Then the portion of a sound wave A, instead of backing out of the horn after one or two reflections, is reflected first from the inner surface of the outer horn H, then from the outer surface of the inner horn S, then again from the inner surface of H, thence to the small end of the horn. Likewise, the portion of the wave lettered B, and therefore all portions of the wave between A and B.

To take care of the energy falling on the *inner* surface of the horn S, a third and still smaller horn may be placed within S, and so on. Thus, by using a number of nested, and spaced horns the energy condensed at the small end is materially increased over anything possible with a single horn.

The shape of the external horn is not necessarily conical, nor is it entirely arbitrary. It is determined by the use to which the horn is to be put, to its length, aperture, and small end diameter, to the distance to the sound source, to the extent it is desired to make use of the horn as a sound resonator, and to the pitch and quality of the sound to be amplified or condensed.

Figure 2 shows both horns, H and S of the same shape. This is not always the most efficient design. The shape of the outer horn having been decided upon, the inner horns are so shaped as to condense the maximum amount of energy at the small end. They are supported by radial strips of sheet metal placed with the plane of the strips parallel with the common axis of the horns, in order to give minimum interference to the passage of sound waves through the system.

The writer is still experimenting with multiple horns of different designs, in order to determine the one having the maximum efficiency. An account of this work, with data, will be published later.

LOCOMOTIVE WHISTLE EXPERIMENTS.

ARTHUR L. FOLEY, Indiana University.

A study of the amount of steam, and consequently the amount of coal, required to blow an ordinary locomotive whistle, the probable average time per day the whistle is blown, and the total number of locomotives in use, convinces me that we "pay dearly for the whistle". Is it not possible to reduce the cost and the coal waste?

In the first place, it would seem that the position of the whistle is bad. It is almost always behind the smoke stack, and frequently behind or at the side of the steam dome, bell or sand box. Sound shadows are not pronounced like light shadows. Nevertheless sound shadows actually exist. The intensity of the sound along the track in front of a locomotive is certainly somewhat lessened by placing the whistle behind the smoke stack or other objects. But it is much further reduced by the hot gases coming from the smoke stack, which act like a dispersing cylindrical lens. Moreover, the currents of hot air about the walls of the smoke stack and rising from the boiler are both absorbing and dissipating for sound energy. That such conditions are undesirable can not be questioned. The question concerns the magnitude of their effect. Is the reduction in the intensity of the sound along the track sufficient to warrant placing the whistle in front of the locomotive smoke stack, as is the case with the headlight?

A second question. Can one devise a sound reflector that will increase the sound intensity along the track where it is needed and decrease it in other directions where it is not only not needed, but is usually a nuisance?

It has been argued that sound waves are relatively so long that a reflector of ordinary size would have little or no effect. Certainly we should not expect results anything comparable to what we have in

the case of the headlight reflector. But it is wrong to expect nothing. Whenever one places his hand to his ear in order to hear better, he makes use of a reflector many times smaller than the whistle reflector would be, yet the hand gives results. So does a megaphone.

In order to settle the question raised above the writer arranged to measure the intensity of sound in various directions and at various distances from a locomotive blowing a whistle. The Monon Railroad Company kindly placed at my disposal one of their mogul engines, with engineer, fireman, and men to operate the turn table on which the locomotive stood. Instead of moving my point of observation to measure the sound intensity in various directions, I set up my apparatus at the side of the track at the desired distance from the locomotive, and measured the sound intensity as the locomotive was turned on the table. This method has many advantages over one in which the observer changes his points of observation, one of which is that the sound is always traveling over the same surface contour in the same direction with respect to wind, etc. The writer expected to make measurements —first without a reflector, to determine the effect of the position of the whistle, then with a reflector to determine its efficiency. The experiments begun late in the fall, were interrupted by a notice from a family living near the railroad roundhouse that, owing to sickness, the noise would not be tolerated. I hope to continue and complete the experiments in the spring. I shall defer publishing data until the experiment has been completed.

I wish to take this opportunity to thank Mr. H. R. Kurrie, President of the Monon Railroad Company, Mr. J. T. Strubel, master mechanic, and Mr. J. Little, roundhouse foreman, for their courtesy and co-operation.

A METHOD OF MEASURING THE AMPLIFICATION OF TWO OR MORE STAGE AMPLIFIERS.

R. R. RAMSEY, Indiana University.

The method here explained is an adaptation of the potentiometer method of measuring the amplification constant of an electron tube.

In figure 1 (Audio Amplifier) the negative terminal of the filament is connected to the middle point, b, of a potentiometer made of two ordinary resistance boxes. This negative terminal may be connected to the earth also. An alternating E.M.F., generated by a buzzer working through a telephone induction coil, is connected to the terminals, c, c,

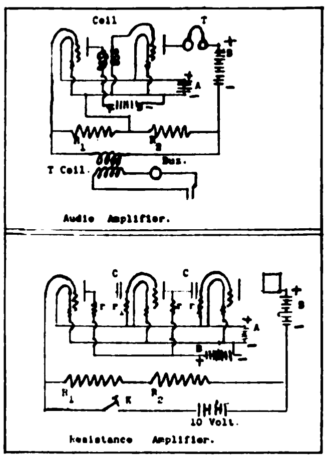

Fig. 1. Diagram of audio and resistance amplifiers.

of the potentiometer. The point, a, is connected to the grid of the first tube and the point, c, is connected through a suitable B battery and telephone to the plate of the last tube.

The tubes are carefully connected with audio frequency coils. The coil must be so connected that when the potential of the grid of tube No. 1 is made positive the potential of the second and of all other tubes is positive. When the grid potential of the first tube is made positive the plate current of all tubes must increase. A second B battery must be used for the plate potential of all tubes except the last.

When the potential of the point a is positive the current runs from a to c through b. The potential of c will be negative, since the potential of b is zero.

If the potential of the grid of tube No. 1 is raised, the current in the plate circuit of the last tube is increased unless the plate potential is decreased. When the plate potential is diminished enough to keep the plate current constant there will be a minimum sound or no sound at all in the telephone.

"Proc. 38th Meeting, 1922 (1923)."

If the resistance R_1 is set at some convenient value, 10 ohms, say, and R_2 is adjusted to minimum sound, then the ratio of R_2 to R_1 is the amplification constant of the amplifier.

$A=R_2/R_1$=Change of plate potential divided by the change of grid potential. If the amplification constant of the tubes has been determined then the amplification constant of the audio coil can be determined. $A=a_1C_1a_2C_2a_3—a_n$.

Where $a_1, a_2,—a_n$ is the amplification constant of the various tubes, and C_1, C_2—is the amplification constant of first, second, etc., coils.

Best results are obtained with two tubes and one coil. The plate potential must be such as to let the tubes operate on a point near the middle of the plate current, grid potential curve. C batteries of suitable value may be inserted in the grid circuits of the tubes, if necessary.

In a resistance amplifier (fig. 1, resistance amplifier) an uneven number of tubes must be used. If the grid of the first tube is increased the plate current increases and the potential of the plate diminishes, causing the potential of the grid of the second tube to diminsh and the plate current of the second tube to diminish. This will cause the potential of the second plate to increase and the grid of the third tube will increase and the current in the plate circuit of tube three will tend to increase.

The resistances in the potentiometer can be adjusted until there is minimum sound as in the first case. A mil ammeter can be inserted in place of the telephone and a battery of a few volts can be placed around a c. A key, K, in the battery circuit is opened and closed and the resistances adjusted until there is no change of deflection.

In this resistance amplifier the actual amplification will be less than the product of the amplification constants of the three tubes. If the resistance, r, is four times the resistance of the tube, then the amplification is four-fifths that of the tube alone. The potential of the B battery must be large. If the tube is to work with 40 volts potential on the plate then the battery must be 200 volts if r is four times the resistance of the tube.

A METHOD OF SECURING ACCURATE HIGH FREQUENCY STANDARD.

R. R. RAMSEY, Indiana University.

In the Trans-Atlantic radio stations of the Radio Corporation of America, Alexanderson alternators are used to generate the high frequency current. The frequency of these alternators depends upon the speed of the rotor. This is regulated by automatic devices so the variation is less than two-tenths of a per cent. A recording device registers the speed every minute.

A radio receiving curcuit containing an oscillating three electrode tube can be tuned until the difference of the frequency of the tube and that of the alternator is some fixed value, for example, the frequency cf a standard tuning fork. Then from the frequency of the fork and the speed of the alternator the frequency of the tube or local radio circuit can be obtained.

These Trans-Atlantic stations operate practically continuously. So the high frequency standard is always available. By arranging in advance the operators of the stations will take special pains to hold the speed constant and will send you the exact speed of the machine covering any particular period.

AN INVESTIGATION OF THE FOLEY TELEPHONE MOUTHPIECE.

JAMES E. BROCK, Sweetser, Indiana.

One of the chief results of Dr. A. L. Foley's photographic studies of sound pulses through horns is the discovery that the condensing power of flared horns is considerably less than what has been taught by physicists heretofore.[1] The heretofore accepted theory is that the condensing power of such horns is inversely proportional to the areas of cross-section of the ends.[2] Researches by Foley, Cloud, and others at Indiana University have shown conclusively that such is not always the case. In fact, it was found that in flared horns there seems to be an

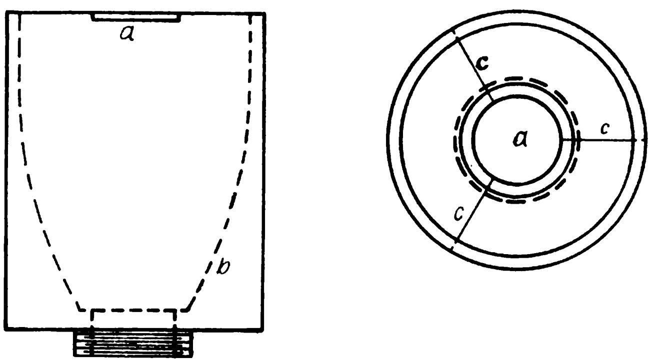

Fig. 1. Foley telephone mouthpiece.

actual "backing out" of some of the energy[3] which enters the wide mouth of the horn, instead of all passing through, as the old theory demands. It was also found that horns having a somewhat parabolic curvature as indicated in figure 1 seemed to have much greater condensing powers than those that are flared in the manner ordinarily found on telephone transmitters. The net result of all these studies was the Foley Telephone Mouthpiece shown in figure 1. As one would expect from the geometry of the parabola a marked advantage of this type of horn comes from the focusing effect of the curve. It was sensed that one very serious fault of the flared horn mouthpiece was the fact that all sound waves created in any instant did not arrive simultaneously at the diaphragm of the transmitter, due to the fact that some of them had to suffer reflections while others traveled directly in without impedence of any kind. This was overcome in the case of the Foley Telephone

[1] A Photographic Study of Sound Pulses Between Curved Walls and Sound Amplification by Horns. Phy. Rev., Dec., 1922.

[2] A. L. Kimball, College Physics. Revised Edition, pp. 196-197.

[3] *Ibid.* See 1.

"Proc. 38th Meeting, 1922 (1923)."

Mouthpiece by suspending a small disc flatwise in the mouth of the horn as indicated in figure 1, *a*, so that all pulses striking the diaphragm would suffer one reflection, and therefore equal retardation. This improvement eliminates a large part of the buzzing and muffled tones common in telephones.

The arrangement of the apparatus used for taking the data in this report is indicated in figure 2, and is a modification of the "hook-up" employed by the Kellogg Switchboard and Supply Company in their common battery telephones.[4] A, A′ are telephone transmitters, shown in the diagram with the ordinary flared horn; R, R′ are adjustable resistances, R having a capacity of about 50,000 ohms and R′ about 10,000 ohms; L, L′ are induction coils (small telephone coils with cores); C is a

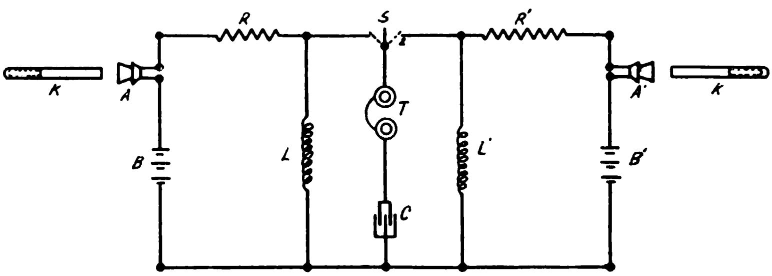

Fig. 2. Hook-up for the experiment.

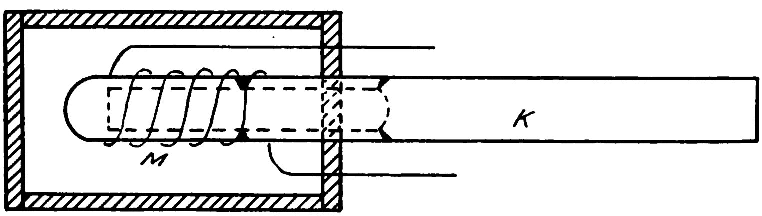

Fig. 3. Heating oven for Knipp Tube.

1/3 m. f. condenser; T a Baldwin mica-disc receiving set; B, B′ are 2 volt storage cells; and S is a double throw switch arranged so that either transmitter could be instantly thrown into the circuit.

In figure 3 are shown the details of the heating oven for the Knipp Singing Tube. M is a coil of three or four turns of No. 28 nichrome wire and was heated on the 110 volt circuit with about 5 amperes of current. The walls of the oven were made of asbestos sheeting, such as is ordinarily used to cover steam pipes, from which the hemp and sisal body had previously been burned so that it would not stain the glass tube. Knipp Tubes were chosen for the experiment because they came more nearly than any other sounding instrument to giving a point source of sound, while tests have shown that the tones[5] given off by

[4] "Principles of the Telephone," p. 99, by Jansky and Faber.

[5] New Standard of Sound Energy. C. T. Knipp. Phys. Rev., Feb., 1920. pp. 155-156.

them are almost pure. The tubes used in the experiments were so sensitive that it was only necessary to heat the wire to a dull cherry red temperature to make them sing in a smooth, loud tone. The especial advantage of the electric heating oven over any open flame was that it gave an even temperature that did not seem to injure the tube by congealing the glass.

As would be expected, it was found that a proper balancing of the capacity and inductances in the telephone circuits gave the best results. Two common telephone coils at L and L′ against a 1/3 m. f. capacity at C seemed to give the best results of any arrangements tried.

Considerable experimenting with different telephone "hook-ups" was done before it was finally decided that the arrangement in figure 2 would be best for our purpose. The theory for the arrangement is as follows: With switch S on contact point 1 the circuit for transmitter A is complete. Any steady currents passing through transmitter A will pass unimpeded through the inductance L, but intermittent or A. C. currents would suffer considerable impedence. The intermittent or A. C. currents set up by the transmitter diaphragm will, however, readily discharge through the condenser and the receiver set. By this arrangement no direct currents flowing in the circuits ever disturb the receiving set T, but practically the whole energy of the A. C. currents created by the vibrations of the transmitter diaphragm will discharge through the condenser. You will notice that both the circuits A and A′ are just alike.

In taking data, one of the transmitters, assume in this case A′, was used as a reference transmitter. The tube K′ was set singing and resistance was "plugged in" in R′ until the sound was just audible in the receivers T, S being set on contact point 2. With this adjustment made the switch S was set on contact point 1 and the tube K set to singing. Resistance was now "plugged in" in R until no difference could be noticed in the intensity of the tone when the switch S was rapidly thrown from point 1 to point 2. (The tubes K, K′ were of practically the same pitch and as nearly the same size as it was possible to make them.) No change was made in the resistance R′ for any set of readings after once adjusted for minimum audibility. The first reading on each horn studied was made with the mouth of tube K just flush with the end of the horn on the transmitter A. Readings were then taken as the tube was moved back to various distances from the mouth of the horn. By placing different types of horns on the transmitter comparisons could be made of the relative intensities of the tones transmitted at any distance. In this research comparisons were made for *no horn*, ordinary *flared horn*, and the Foley Telephone Mouthpiece. The observations were made in an especially arranged, sound-proof room; the walls, floor, and ceiling of which were covered with felt about one inch thick. Long strips of this same felt about one foot wide were also cut and hung edge-wise along the walls and ceiling to break up any reflections that might occur. The singing tubes K, K′ were set at opposite ends of the room, a distance of about twenty feet, and the receiving apparatus was moved out into the adjoining hall. Observa-

tions were made at night, for noise during the day interfered with the hearing of the extremely low tones. All the curves shown have been checked on at least three different evenings and I am certain that the slope and relative intensities at the different distances are as nearly correct as the conditions of the experiment and the apparatus would permit.

Data:

No horn		Flared horn		Parabolic horn		Parabolic horn with disc	
D	R	D	R	D	R	D	R
0.0	30700	0.0	18000	0.0	33000	.5	20000
.5	17000	.5	13000	.5	26000	1.0	23000
1.0	8000	1.5	6000	1.0	23000	2.0	14000
1.5	7000	2.5	5000	1.5	21000	3.5	10000
2.5	4000	3.5	4000	2.0	20000	5.5	7000
3.5	3000	5.5	1600	2.5	18400	8.0	3000
5.0	2900	7.5	600	3.0	14000	11.0	1000
7.0	1400	11.0	200	3.5	11000	14.0	400
10.0	1000	15.0	000	4.0	7000		
13.0	200			4.5	5000		
16.0	100			5.0	4400		
				7.0	3000		
				9.0	2000		
				11.0	1000		
				14.0	1000		
				19.0	800		
				23.0	400		

Above is the data for the four curves shown in figure 4. D is the distance from the mouth of the horn to the nearest end of the singing tube. R is the resistance "plugged in" in the test circuit A to reduce the tone to the same intensity as that in the reference circuit A′.

It is noticed there is a marked superiority in the Foley Telephone Mouthpiece (parabolic horn) as is shown by the curves 3 and 4 (fig. 4), and that this superiority holds especially at the ordinary speaking distances of from 5 cm. to 10 cm. It was necessary to plug in almost twice as much resistance in the circuit at 5 cm. to reduce the intensity of the parabolic horn to minimum audibility as for the *No horn,* and the ratio is about 5 to 1 for the flared horn. This increased efficiency is probably due in no small part to resonance[6] in the horn and is as marked for the speaking voice as for the pure tone of the singing tube. When the small disc was inserted in the mouth of the horn so that the focusing effect was a maximum the efficiency was considerably increased for 4 cm. to 9 cm. as is shown by curve 4. This curve exhibits a freakish tendency to rise upward until a distance of about one centimeter is reached when the slope reverses and it drops off in a smooth curve. This tendency of the curve to rise for a short distance was probably due to the shielding effect of the disc when the source is near to it. The

[6] D. C. Miller. The Science of Musical Sounds. pp. 156-159.

high sensitivity of the *no horn* curve at zero distance is undoubtedly due to the fact that the diaphragm of the transmitter was almost adjacent to the tube so that the total energy given off at the source was almost all absorbed by the vibrating disc. The rapid falling off of the curves shows vividly how the energy falls off with distance out from the horn.

The apparatus was also used to make some investigations of the sound pattern about the mouth of the singing tube for which it seemed

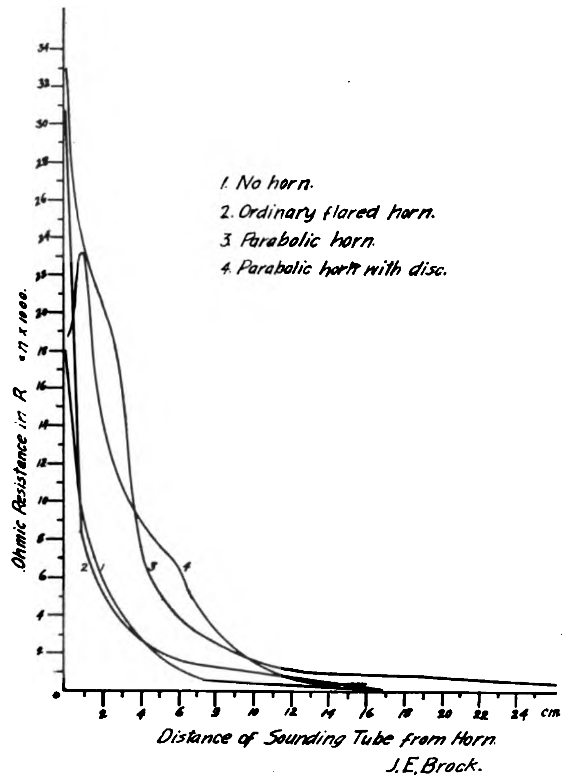

Fig. 4. Graph of curves showing superiority of the parabolic horn.

to be singularly well adapted. The energy given off by the singing tube seemed to be largely confined to a cone shaped region in front of the tube with the mouth of the tube at the apex. The boundaries of this sound cone seemed to be very sharply defined. It is hoped that in a short time enough data will have been secured so that more definite ideas may be formulated concerning the sound pattern of this cone.

In concluding I wish to express my thanks to Dr. A. L. Foley, of Indiana University, and Dr. C. T. Knipp, of the University of Illinois, for their kindly interest and many helpful suggestions offered during the progress of the experiments outlined in this research.

THE OCCURRENCE OF SECONDARY PARASITISM IN THE FROG.

GEORGE ZEBROWSKI, Purdue University.

In a series of experiments on the life histories of certain Anuran parasites, especially those of *Rana pipiens*, conducted under the direction of Dr. H. E. Enders, several cases of secondary parasitism have been observed, two of which are described in this article.

By secondary parasitism is meant the occurrence of parasites in forms which themselves lead an essentially parasitic existence. To the uninitiated the mention of a parasite often brings to mind a few common forms such as the louse, the flea, the tick, or perhaps a tapeworm. Unless one is actively engaged in the study of parasitology, it is difficult to appreciate the tremendous number of parasitic forms that may be found at one's very elbow. Indeed, it may be conservatively stated that every animal, during its lifetime, is a host to one or more species of parasites which are dependent upon it for their existence.

This statement is prompted by a small, moribund, leopard frog, which the writer recently dissected and which contained the following astonishing list of parasites:

FLATWORMS.	
Pneumonoeces coloradensis, in lungs,	5
Loxogenes arcanum, encysted in musculature of stomach and intestine,	14
Clinostomes (sp.?), immature forms encysted generally,	137
Diplodiscus temperatus, in rectum,	5
Gorgoderina attenuata, in bladder,	3
ROUNDWORMS.	
Angiostoma nigrovenosum, in lungs,	7
Strongylus auricularis (?), in intestine,	4
Small, immature, active, free-living nematodes, (species?), in body cavity,	17
PROTOZOA.	
Opalina, and Nyctotherus, several hundred in intestine and rectum.	

The infestation of parasitic forms by other parasites is a common phenomenon, and especially is this true in the case of Protozoa. Thus, the orders Flagellata, Gregarinida and Coccidiidea are replete with parasitic species that may be dependent upon other parasites, commonly insects, for their transfer to a final host. The Trypanosome of "sleeping-sickness" and *Plasmodium vivax*, the causative agent of malaria, are two of a number of well known examples which may be cited. It is true that secondary parasitism among the higher metazoa is more difficult to find, but this is probably due to lack of research, rather than to a lack of material. It is now definitely known that fleas are intermediate hosts for larval stages of certain tapeworms. We have also good reason to believe that other helminth forms can be transferred by insects in this way. Doubtless this list could be further augmented, but

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the examples already cited will suffice to show some of the parasite relationships that may be found. They indicate moreover, the economic value of studies in this field.

To the above list the writer would contribute a new form of parasite relationship, namely, the occurrence of Distome larvae in other immature parasites. The only analogous case of which we have any

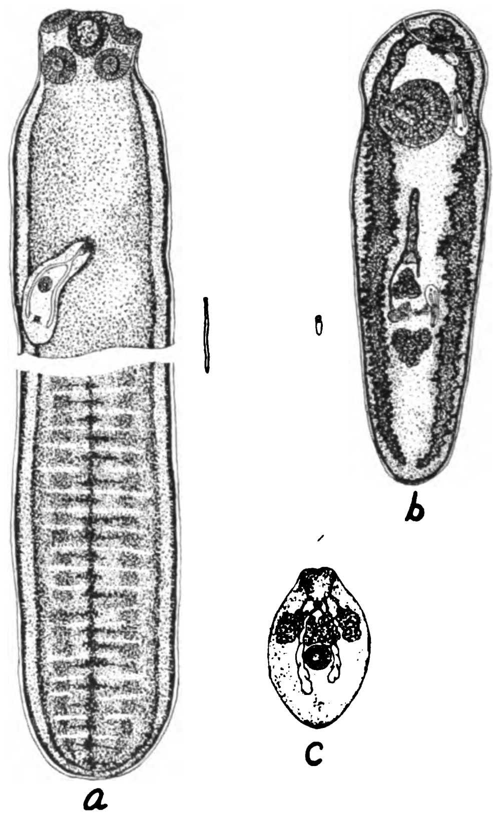

Fig. 1. a, Anterior and posterior ends of larval cestode, showing Distome larva parasite in anterior portion, x 12; b, immature *Clinostomum marginatum* parasitized by three larval Distomes, x 12; c, *Agamodistomum marcianae* (?), the larval Distome infesting the above parasites, x 25. The small figures indicate one-half natural size.

record is one reported by Cort[1] in which a Trematode was parasitized by Gordius larvae. In the accompanying figure are shown two parasitic forms in which secondary infestation was found. The first (fig. 1a) is an immature Cestode, one of seven specimens taken from the same liver. These were free-living rather than encysted forms and were woven in and out throughout the parenchyma of the liver. They were

[1] Cort, W. W. Gordius Larvae Parasitic In a Trematode. Jour. Parasit., 1:198-199. 1915.

teased out with the greatest difficulty, and when isolated, were glistening white in color, ranged in length from one to three inches, and possessed a well defined scolex with four suckers but no hooks. These Cestodes were also peculiar in having a cylindrical body. The available records of Anuran Cestodes list but three species from this country. These are, *Nematotaenia dispar* Goeze 1782, *Taenia pulchella* Leidy 1851, and *Cylindrotaenia americana* Jewell 1916. Jewell[2] considers the last two identical, and also questions the occurrence of *Nematotaenia dispar* in North America. If these contentions are valid then the Cestodes under discussion are either a new species or identical with *Cylindrotaenia americana.* They unquestionably belong to the Nematotaeniidae, even though from their immature condition the species could not be determined with certainty.

The second (fig. 1b) shows the larva of *Clinostomum marginatum*[3] taken from a subcutaneous cyst. These forms always occur encysted singly, and are very abundant, it being nothing unusual to find several dozen in a single frog. From personal observation it would appear that two species are concerned. The first is a relatively large form with a smooth cuticle, while the other is a smaller, more slender form, with a spiny cuticle. It may be that these are different stages in the development of the same species. A fair degree of dexterity is needed to separate these forms from their tough membranous sheaths without injury. However, when once liberated they are active and extensile to a degree. In conducting the experiments already outlined, three of these Clinostomes and one Cestode were found that showed infestation, presumably with the same species of parasite. The illustrations for the figure were prepared from specimens mounted *in toto*, and stained with equal parts of acid carmine and alum cochineal. Attempts to measure living material were unsuccessful as these animals changed their shape too rapidly to yield accurate results.

The parasite found infesting the above forms was a diminutive larval Distome shown in figue 1c. In this case the specimen was teased out of one of the Clinostomes already mentioned and this illustration, like the others, was drawn to scale from a prepared mount. Careful search elicited the presence of these parasites in practically every frog examined, while in some individuals literally hundreds were found. These forms were active, free-living, and migrated extensively throughout the tissues of the host. The easiest way to obtain them in number was to scrape the inverted skin of a frog in normal salt solution. In the fine residue thus obtained numerous Distome and other larval Trematodes could usually be found under the microscope. Living specimens showed a well defined forked digestive tract and an emulsified structure of the protoplasm. They were unusually active and extensile, changing their shape continually in the process of locomotion. They were also more slender than the drawing would indicate, as the mounted

[2] Jewell, Minna E. Cylindrotaenia americana nov. spec. From the Cricket Frog. Jour. Parasit., 2:181-191. 1916.

[3] Osborn, H. L. On the Distribution And Mode Of Occurrence in The United States And Canada Of Clinostomum Marginatum, A Trematode Parasite In Fish, Frogs And Birds. Biol. Bull. No. 5, Vol. XX, pp. 350-367. 1910.

specimen is much shrunken and fore-shortened. These forms occurred chiefly in the connective tissues of the host, but could be found generally throughout the body, as in the lungs, the digestive tract, the body cavity, and in the liver and spleen. In these last their presence was indicated by gray, granular, necrotic patches upon the surfaces. On several occasions these Distomes were observed in the web of a frog's foot, where they seemingly had no difficulty in making their way, moving rapidly across the field of the microscope.

The extent to which these Distomes are true parasites of the forms they infest is problematical. In all cases where this infestation occurred an excessive number of free-living Distomes were also found in the tissues of the frog. In neither the Cestode nor Clinostomes were these secondary parasites encysted, a fact which would suggest a fortuitous occurrence. It seems altogether probable that in their extensive migrations these small forms could accidentally force their way into other parasites, especially if the body substance of these offered less resistance than did the tissues of the primary host. These secondary parasites varied considerably in size, but were of the same general appearance. Because of their immature condition no exact identification is attempted. In their gross anatomy they agree closely with *Agamodistomum marcianae*,[4] a cercaria described by Cort as follows: "The ventral surface is completely covered with spines which are very thickly set over the anterior tip and somewhat scattered in the post-acetabular region. The margin of the acetabulum is armed with two or three rows of closely set spines pointing in, which are so placed that they add greatly to the gripping power of the sucker. The host in which *Agamodistomum marcianae* complete its development is not known. Also its structure at this stage gives little clue to the systematic position of the adult. The character of its cephalic glands and excretory system, however indicates that it has developed from a forked-tailed cercaria."

[4] Cort, W. W. The Excretory System Of Agamodistomum Marcianae (La Rue). The Agamodistome Stage Of A Forked-Tailed Cercaria. Jour. Parasit., 4 130-134. 3 figs. 1918.

NOTES ON THE MAMMALS OF THE DUNE REGION OF PORTER COUNTY, INDIANA.

MARCUS WARD LYON, JR., South Bend.

The following notes on the mammals of the dune region of Porter County are based primarily on a small collection which was made during a brief camping trip into the dunes during the autumn of 1922. They are supplemented by observations on mammals seen but not captured during that trip and numerous Sunday excursions and on reports of apparently good authority. So far as I am aware there are no previously published comprehensive records of the mammals of Porter County. These notes contain little of novelty, but it seems desirable to publish them because owing to the invasion of the region by week-end visitors, the erection of permanent cottages along the lake front, and more or less extensive forest fires it is not unlikely that the biological aspects of this very interesting region will be rapidly altered. Many animals and plants now common in the region are probably destined to disappear as completely as the once common Virginia deer.

Our tent was pitched in a sheltered spot a few yards back from the lake front and about 50 or 60 feet above its level, north of Mineral Springs station of the Chicago, Lake Shore and South Bend Railway. Traps were set in the neighborhood of our camp and westward to opposite Oak Hill station.

Acknowledgement is here made of the valuable assistance of my wife, Dr. Martha Brewer Lyon of South Bend, not only for help in placing traps and looking for mammals but also for acting as chef, etc. while I skinned specimens. Special thanks are also due to Mr. H. W. Leman of Chicago, for the privilege of camping on his property, and to Mr. Gerrit S. Miller, Jr., of the United States National Museum for assistance in the identification of specimens. The specimens collected have all been deposited in the National Museum.

As is well known the sand dunes at the southern end of Lake Michigan are not barren tracts of sand. They present a variety of physiographic features and characteristic associations of plants, if not of mammals. In a general way these may be briefly described as follows.*

The beach proper: This is the area between the calm low water level of the lake and the rough high water level. It is practically devoid of permanent vegetation. While perhaps most of the beach area is dependent upon the size of the breakers formed after every heavy northerly wind on the lake, some of it is evidently due to actual changes in the water level. Northern winds seem to blow the water shoreward as well as to throw it into large waves, while an off shore wind blows it away again. Differences in barometric pressure over different areas of the lake may also have an effect in altering the water level. Even

* For a detailed description of the various associations in the region see *A Naturalist in the Great Lakes Region* by Elliott Rowland Downing, 1922, and for topographic features *Rand McNally's Map of Indiana Dunes* by P. S. Goodman [1920].

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on essentially calm days the water does not always appear at the same level.

The fore dune region: The fore dunes are low wind-blown piles of soft sand immediately back of the high water mark of the beach and parallel with the water line. Vegetation on them is not abundant in kind or in number, but is not inconspicuous. The most characteristic plants are sand reed-grass, *Calamovilfa longifolia;* maram grass, *Ammophila arenaria;* and sand cherry, *Prunus pumila.* This area gradually blends in with the higher wooded dunes, bare faces of which are characterized by the same association of plants. Around the margins of blowouts (wind-worn cuts into the larger, wooded and more mature dunes) an association of plants similar to those of the fore dunes occurs mingled with plants of the first portions of the wooded dunes. The only mammals found in the fore dune region were the Baird deer mouse, *Peromyscus maniculatus bairdii* and a few house mice, *Mus musculus.* As the same species of deer mouse was found in an interdunal meadow it can not be considered a characteristic inhabitant of the fore dunes.

Wooded dunes: These are the characteristic dunes of the region and occupy the greatest area. They are immediately back of the fore dunes and range in height from 50 to 150 feet. They are covered with permanent vegetation. According to the abundance of certain plants on them and to their proximity to the lake the wooded dunes may be roughly divided into a lakeward portion characterized by an abundance of such plants as white pine, *Pinus strobus;* jack pine, *Pinus banksiana;* common juniper, *Juniperus communis;* red cedar, *Juniperus virginiana;* red osier dogwood, *Cornus stolonifera;* aromatic sumac, *Rhus canadensis;* fox grape, *Vitis vulpina;* basswood, *Tilia americana;* and a considerable number of white and black oaks, *Quercus alba* and *Q. velutina;* and into a landward portion where the oaks predominate and where there is usually a dense growth of blueberry, *Vaccinium pennsylvanicum.* The two portions are not sharply defined but the vegetation has a tendency to be disposed as mentioned. The lakeward portion of these dunes is quite uniform in height, ranging about 50 or 60 feet, and the vegetation of their north faces blends in with that of the fore dunes. The landward portions vary considerably in height and may be only low hills or ridges or rise to high hills of 150 feet. The wooded dunes are often broken into by blowouts and their landward slopes are often being covered by advancing sand. The common deer mouse, *Peromyscus leucopus noveboracensis* was very abundant in the wooded dunes.

Interdunal meadows and ponds: These are open treeless stretches between the wooded dunes and toward the landward side. They may be permanent meadows or permanent shallow ponds, or meadows which early in the season were shallow ponds. Around the edges of the permanent or temporary ponds there is always more or less meadow. These meadows are covered with a variety of annual and perennial herbaceous plants varying considerably in different meadows and drying ponds. Some of the meadows are quite damp and may contain much sphagnum and masses of such plants as cassandra, *Chamaedaphne calyculata,* chain fern, *Woodwardia virginica,* and sundew, *Drosera intermedia.*

About the edges of such meadows and ponds the sour gum, *Nyssa sylvatica* is found quite characteristically. Although such places appear to be quite ideal for many species of mammals, yet comparatively few runways or other signs of mammals were found in them. The species taken were the common deer mouse, *Peromyscus leucopus noveboracensis;* on one occasion, the Baird deer mouse, *P. maniculatus bairdii;* prairie and pine voles, *Microtus ochrogaster* and *Pitymys pinetorum scalopsoides*, and the short-tailed shrew, *Blarina brevicauda talpoides.*

Subdunal swamp or marsh: Between the tracks of the Chicago, Lake Shore and South Bend Railway and the dunes proper is an extensive area of low ground, almost as low as the level of Lake Michigan. At Mineral Springs station the track is said to be 13 feet above the lake level and the track is higher than the swamp. Part of this low ground drains into the lake at Waverly Beach by Dune Creek. Toward Michigan City much of this low ground is being cultivated and from most of the other treeless portions much hay is cut. Most of the subdunal swamp or meadow is treeless, but near the dunes in many places it is timbered with such trees as tamarack, *Larix laricina;* white pine, *Pinus strobus;* yellow birch, *Betula ·lutea;* occasionally, paper birch, *B. papyrifera;* red maple, *Acer rubrum;* elm, *Ulmus americana;* speckled alder, *Alnus incana;* and tupelo, *Nyssa sylvatica.* A conspicuous shrub in this area is the poison sumac, *Toxicodendron vernix.* Opposite Mineral Springs this wooded portion is usually termed the tamarack swamp although tamaracks are by no means the most common trees. Farther west white pines predominate, in places the floor being almost solid with their needles. Parts of this subdunal swamp are very boggy, containing such vegetation as pitcher plants, *Sarracenia purpurea;* cranberry, *Oxycoccus macrocarpus,* etc. In many places it is comparatively easy to sink to considerable depth in the more boggy portions. It is in such places if they should ever be explored or drainage ditches cut into them that one might expect to find remains of large mammals, elk, deer, bison which had become mired there years ago when such species were common in Indiana. In this subdunal swamp traps were placed in various sections excepting in the extremely boggy areas. The deer mouse, *Peromyscus leucopus noveboracensis*, was the common mammal. In the open portions of the marsh rattle-snakes, *Sistrurus catenatus* are frequently taken, especially during haying.

Dune Creek: This is a small sluggish stream draining part of the subdunal swamp. It starts in the Furnessville region and flowing slowly westward and northward empties into Lake Michigan just west of Waverly Beach. Most of its course is through swampy woods. Owing to lack of time no trapping was done along its course.

Mammals Collected in the Dune Region of Porter County or Mammals Observed in the Region.

Opossum (*Didelphis virginiana* Kerr): A few years ago near Dune Park Dr. and Mrs. W. D. Richardson found the dead body of a mature opossum and on another occasion found a half-grown young.

Prairie mole (*Scalopus aquaticus machrinus* Rafinesque): Residents

state that moles are not uncommon in the region, but they have escaped my personal observation. Wood (6) reports moles as very common on the dunes of Berrien County, Michigan. Runways such as made by moles are very common in the wooded dunes and I have even seen one such runway in the open sand at the top of a blowout. Traps set in these runways yielded many deer mice, occasionally prairie and pine voles, but never moles. It is well known that pine voles make runways essentially like those of moles and the evidence points to the vole as a more frequent maker of such runways in the wooded dunes than the mole.

Short-tailed shrew (*Blarina brevicauda talpoides* Gapper): Five specimens secured, a pair taken in traps in runways in sphagnum and cranberry at edge of an interdunal pond, one in a white pine swamp, and two in the treeless portion of the subdunal swamp. None were taken in the wooded dune region. This shrew did not appear to be common. Very rarely were any of the numerous collected deer mice ever molested in a manner suggestive of the usual depredations of short-tailed shrews. Traps were usually baited with bacon as a special inducement to shrews. Of the two taken in the sphagnum and cranberry, one was captured on checking up the trap line backwards after the night's catch had been taken out thus showing these shrews to be active by day and to be little frightened by persons working around their habitat. Measurements of the two males: total length 122, 103; tail 28, 21; hind foot 17.5, 14 mm. Of the three females: 112, 118, 105; 22, 28, 21; and 15, 17, 15.5 mm.

Red bat (*Nycteris borealis* Mueller): One afternoon in mid-summer I saw a curious looking object in some blackberry bushes. Almost as soon as I recognized it to be a female red bat it flew away. Bats are frequently seen on summer evenings and probably represent most of the species of bats recorded for the state by Hahn (4). The red bat is the only one seen sufficiently close to admit of identification. No specimens were secured.

Timber wolf (*Canis lycaon* Schreber): Timber wolves have probably been extinct in the dune region for some years. Residents state that wolves have been seen recently and if such is the case the animals are most likely the prairie wolf or coyote. Dice (2) records timber wolves as having been taken at Lakeside, Berrien County, Michigan, about 1909 and says that in 1911 four were killed southwest of Three Oaks, Michigan, just over the Indiana line, scarcely 20 miles away. Among some deer bones picked up in a blowout was a considerable portion of the left ramus of a member of the genus *Canis*. The carnassial is the only complete tooth in it. It measures (crown) 25 x 10 mm., height of main cusp 13 mm. The length of premolar and molar series of teeth (alveoli) is 83 mm. Mr. Gerrit S. Miller, Jr., says the carnassial "is below maximum for dog and therefore not diagnostic of wolf, though its size is rather great".

Prairie wolf or coyote (*Canis latrans* Say): Probably the animal referred to by residents when they say that wolves still inhabit or have lately been seen in the dune region. The species is not recorded by

Dice nor by Wood as among the mammals of Berrien County, Michigan, though the latter author (6) refers to its occurrence in Washtenaw County, Michigan, as late as 1910. Hahn (4) records it from Jasper and Laporte counties, Indiana, as late as 1903 and 1906. Newspaper accounts in October, 1922, state the presence of wolves, probably this species, in swamps near Leesburg, Kosciusko County. No fragments of coyotes or first hand evidence of their present occurrence in Porter County were obtained.

Red fox (*Vulpes fulva* Desmarest): This animal is apparently not rare in the dunes though not very frequently seen. Residents state that a small number are obtained each season for their fur. One was seen by my wife October 1, 1922. When we camped in Big Blowout in 1921, the tracks of what were apparently those of a fox were found on the slope of the blowout within several yards of our tent and in a comparatively straight line along the fore dune region for about half a mile. During the past summer, not far west of Michigan City, we found a large burrow in a hillside. It was much too large for a woodchuck's burrow and although no identifiable tracks were found about it, we believed it to be a fox den.

Raccoon (*Procyon lotor* Linnaeus): Residents state that a few "coons" are taken each season for their fur. I have no personal knowledge of the animal and I have never been fortunate enough to find foot prints that might have been made by it.

Weasel (*Mustela noveboracensis* Emmons): These animals are fairly common in the region, though I have never seen any. Mr. A. F. Didelot who has trapped about 200 specimens of weasels in the past three winters in the region of the dunes and near Chesterton, says that only two of that number were in white pelage. In Washtenaw County, Michigan, Wood (5) says only about 75 per cent of the weasels change to the white coat in winter. The percentage of those changing in northern Indiana appears to be much smaller.

Mink (*Mustela vison* Schreber): A number of minks are said to be trapped each season in the region. One dead specimen was collected on the bottom of a dried interdunal pond in a spot which had been covered with water two weeks before. The body gave the impression of not having been dead for more than a week or ten days.

Eastern skunk (*Mephitis nigra* Peale and Beauvois): Skunks are fairly common in the region and a number are taken each season for fur. By November 30, 1922, R. W. Sabinske had taken seven. He gave me two carcasses that he had not yet thrown away. They were covered with an enormously thick layer of fat. Their stomachs contained unidentifiable ground up material and a few small roundworms. His skins were all turned inside out, but he said they ranged in color from solid black except for a white patch on head to a specimen in which white predominated. There seems to have been some doubt as to the identity of the skunk in the dunes. Dice (2) uses *Mephitis nigra* for the animal of Berrien County, Michigan. Hahn (4) thinks the eastern skunk is one commonly found in the state, but in speaking of the Illinois skunk, *Mephitis mesomelas avia*, he says "It is very probable that this is the

species inhabiting all the northern part of the state". According to Cory (1) the region under consideration is in the area of intergradation of *Mephitis mesomelas avia* with *M. m. putida*. A. H. Howell of the Biological Survey has identified the two skulls given me as *Mephitis nigra*.

Northern deer mouse (*Peromyscus leucopus noveboracensis* Fischer): This deer mouse is the commonest mammal in the region. It was found in every situation except in the low dunes along the lake front where it appears to be replaced by the Baird deer mouse. The percentage of traps holding deer mice ranged from 10 to 40 a night except when the traps were placed in the fore dunes. Of the three baits employed, rolled oats, peanut butter, and bacon, the latter seemed to be the most effective. Several were taken in larger traps baited with apple and set for squirrels and chipmunks. They were quite common about our tent and helped themselves to exposed food. In addition to these taken opposite Mineral Springs, one of this species was taken in a wooded dune opposite Furnessville in 1921.

Most of the adult males were in a rather bright yellowish pelage although three or four had a short-haired coat of a sort of house mouse gray. In the case of the females about half were in a bright and yellowish pelage while the rest were in a short-haired house mouse gray coat. Only three young specimens in a "blue" pelage were saved. Two of these show an incoming yellowish coat on the sides.

Three stages of development are represented among the specimens collected, breeding adults, animals which have reached adult size and coloration but not yet breeding, and young specimens in the "blue" coat. In addition to these very immature young were noted. Of 18 mature females all were apparently nursing young, none being pregnant. The impression was gained that reproduction was carried on at regular intervals and simultaneously by nearly all the mice. On the spot where our tent was placed another party had previously camped leaving much food around and many pasteboard boxes. On our arrival, there was noticed in one of these boxes a Peromyscus nest, made of torn bits of paper after the manner of house mice. It contained several young covered with hair but unable to walk. On examining the nest a few hours later it was found the young had been carried away. As the previous occupants of the site had left Sept. 4 and we had come there Sept. 26, the mice had evidently built the nest and reared young of small size in the course of three weeks. The mammae are pectoral 1/1, inguinal 2/2=6.

In subterranean runways in which traps were placed for pine voles, deer mice were so often taken as to make one wonder if some of these runways may not have been made by them. In some of the interdunal meadows which had been quite wet or even covered with water earlier in the season were numerous holes apparently the work of crayfish though only rarely was anything suggesting a "chimney" seen. Traps set about these holes frequently yielded northern deer mice, some being caught in such a manner as to indicate that the animal had been in the burrow at which the trap was placed. Once a crayfish was caught in a trap placed at these burrows. W. D. Richardson states that deer mice frequently enter his cottage and have the same activities as house mice in cities.

The activities of these mice at night could be well inferred from their footprints in the sand the following morning providing the night had been still. Such footprints were well observed about our tent, and about the fox grapes, red osier dogwood, and grasses, plants growing out of clear sand. The usual mode of locomotion appeared to be a jump using all four feet at once. The tail appeared to have been carried in the air as no marks of it were left in the sand. The longest jumps were from 10 to 12 inches, but usually they were much shorter being but little more than the length of the animal. Only rarely did one find foot impressions showing that the animals had been walking and sometimes, in such cases, what appeared to be tail marks could be seen.

Extreme and average measurements of ten adult males: total length 180, 172, 160; tail 82, 79, 75; hind foot 22, 21, 20 mm. Of ten adult females: 187, 176, 172; 88, 80.5, 75; 21.5, 20.5, 20 mm.

Between five and ten per cent of these mice captured were infested in the inguinal region with a large fly larva, perhaps *Cuterebra emasculator*. These larvae seemed well advanced in development, ranging between 10 and 15 mm. in length. Only one larva was found to a mouse. On one occasion a particularly large larva emerged from its sac in a dead mouse. The others remained within until removed in the process of skinning. The majority of the mice infested were nursing females. Only one was noticed in a male in which case the swelling caused by the subcutaneous larva superficially resembled a swollen testicle.

Baird, or prairie, deer mouse (*Peromyscus maniculatus bairdii*, Hoy and Kennicott): Eleven specimens of this mouse were secured, nine being taken in the fore dune area amid *Calamovilfa longifolia* and *Prunus pumila*, and two in an interdunal meadow. The latter were caught in traps set near holes that appeared to have been made by crayfish. Besides the two captured in this meadow a third got into a trap and left only its tail. None of the traps set in this meadow secured *Peromyscus leucopus noveboracensis* or other mammals. With the exception of two house mice, the Baird deer mouse was the only mammal taken in the fore dunes. Traps set at the top of a blowout about 150 feet above the lake and where much *Calamovilfa* was growing yielded only the northern deer mouse. The Baird deer mouse does not appear to be very common. On one occasion 80 traps were placed in the fore dune area and not a specimen of any kind was secured and on another occasion 78 traps were placed in the fore dunes and only two of this species and a house mouse were secured. Hahn (4) did not find this species very common in the state, recording it from only five counties. Evermann and Clark (3) record three specimens from Lake Maxinkuckee region and state: "It is very abundant in the sand dunes that border Lake Michigan".

What these mice do with themselves during the day, at least in the fore dune region, is difficult to say, unless they dig down into the sand. Only once I found what appeared to be a burrow. A trap placed near it yielded nothing. As the habitat of these mice is much sandier than that of the northern deer mouse their nightly activities were much more visible. Judged by the large number of foot prints and the small number

of mice taken the individual mice are quite active. Like the other species of deer mouse their usual mode of progression is by jumping on all four feet at once. Only rarely does one find tracks apparently made by

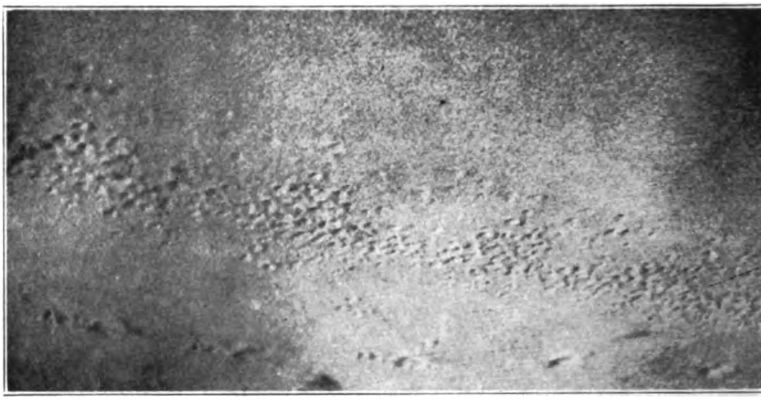

Fig. 1. Course of Baird's Deer Mouse, *Peromyscus maniculatus bairdii*, in dry sand.

walking, in which case what appear to be tail marks are sometimes present. In the jumping mode of progression the tail does not touch the ground. There seemed to be a tendency for the animals to jump along the same course or else for the same animal to jump back and

Fig. 2. Footprints of Baird's Deer Mouse, *Peromyscus maniculatus bairdii*, in dry sand.

forth along it. The sand was often well marked by their tracks into almost a runway, usually in a direction parallel to the axis of the low dunes.

The mammae are pectoral 1/1 inguinal 2/2=6. Of the four females

taken only two were adult, one was nursing and the other contained four fetuses, each about 20 mm. in length.

This species although closely resembling the more common northern deer mouse is readily distinguishable in the adult state by its darker coloration and more sharply bicolored tail, as well as by its smaller size, shorter hind foot, and shorter tail. Immature specimens of the two species are almost indistinguishable in point of color, but are apparently easily distinguished by measurements. Five adult or nearly adult males give these extreme and average measurements: total length 150, 141, 130; tail 62, 57, 52; hind foot 18, 17.7, 17 mm. Two adult females measure respectively, 148, 137; 60, 52; 17, 18 mm.

One of the specimens of this species was infested in the inguinal region with a fly larva, similar to the one found in the northern deer mouse.

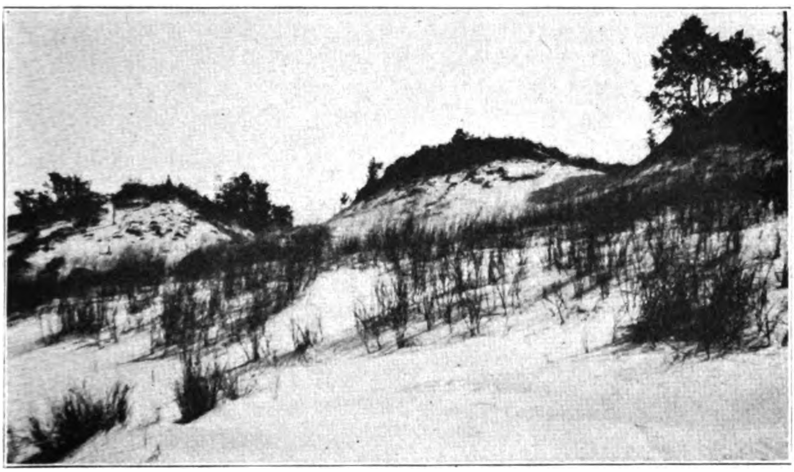

Fig. 3. Habitat of Baird's Deer Mouse, *Peromyscus maniculatus bairdii*, the low fore dunes in the foreground covered with *Calamovilfa longifolia.*

Prairie vole (*Microtus ochrogaster* Wagner): Represented by seven specimens, three adult or nearly so and four young. Three of the specimens, an adult and two young were taken in a wooded dune, though near a meadow, in subterranean runways in traps specially set for pine voles. The others were taken in an interdunal meadow in traps placed at random on the ground as no runways were discernible. Although traps were placed in four different interdunal meadows, in only one were these voles taken. It may be that colonies are somewhat local in distribution. One female was nursing, mammae: pectoral 1/1, inguinal 2/2=6. Three stages of growth appear to be present, breeding adults, half grown young, represented by four immature specimens, and very young represented by those belonging to the nursing female. Hahn (4) records this vole as being rather generally and commonly distributed throughout the state. Dice (2) found it common in Berrien County, Michigan.

Pine vole (*Pitymys pinetorum scalopsoides* Audubon and Bachman): Two specimens of this species were secured, a male in a runway in damp sphagnum and cranberry at the edge of an interdunal pond, and a female taken in a wooded dune in a trap set in a subterranean runway. Upheaved subterranean runways like those made by moles are very common in the wooded portions of the dunes. On one occasion such an upheaved runway was found on top of a blowout in sand not stiff enough in places to hold up. Whether all these runways are made by pine voles can not be said. Traps placed in them yielded chiefly deer mice. One of the present species was taken in them and two *Microtus ochrogaster*. I failed to capture moles and short-tailed shrews in such runways but perhaps they were insufficiently set with traps. These two specimens of pine vole are the most northern taken in the state. Hahn (4) says he has not taken this species in the northern part of the state, Wabash County being his most northern record. Evermann and Clark (3) record one specimen from Marshall County. Dice (2) records it from Berrien County, Michigan. Measurements of the two specimens, male and female respectively: total length 122, 122; tail 22, 22; hind foot 16.5, 17.5.

Muskrat (*Ondatra zibethica* Linneaus): Some muskrats are said to be trapped for their skins each winter, being found in the subdunal great marsh and in interdunal ponds such as Little Lake and Walker Lake. In dry seasons, as in 1922, they must become quite terrestrial.

Norway, or common house rat (*Rattus norvegicus* Erxleben): No specimens seen or taken. Residents say rats are sometimes found about the outbuildings of the store at Waverly Beach. As the region becomes more populated rats will probably form a constant part of the fauna.

House mouse (*Mus musculus* Linnaeus): In spite of the large number of week-end visitors to the dunes who leave much food scattered about, and the numerous cottages toward Waverly Beach the house mouse does not appear to be common in the region. Only two specimens were secured, each in the fore dune area, one in 1921 when we were camped at Big Blowout, opposite Furnessville and over a mile from any permanent dwelling, and one in 1922 not more than 300 yards from a cottage occupied every week-end. W. D. Richardson states that the only mice he has observed in his cottage are deer mice. The adult female taken in 1922 measures: total length 172, tail 85, hind foot 18 mm.

Thirteen-striped spermophile or ground squirrel (*Citellus tridecemlineatus* Mitchill): This species is not uncommon along the Chicago, Lake Shore and South Bend Railway just south of the dunes. In the dunes proper just north of Oak Hill station and a few feet above the subdunal swamp my wife saw one of these spermophiles. It is not improbable that these animals have entered the region by following the railway and that the one seen opposite Oak Hill had followed the road leading from the station to the dunes.

Chipmunk (*Tamias striatus* Linnaeus): Chipmunks do not appear to be very common in the dunes. I have only one record of them in my notes but feel certain I have seen more than one. None were trapped though suitable traps baited with apples were set in what appeared to

be good chipmunk territory. Wood (6) says it is rare in Berrien County, Michigan, and Dice (2) seems to record but a single specimen. There is some doubt as to the race of chipmunk inhabiting Indiana. Hahn (4), and Evermann and Clark (3) refer the Indiana chipmunk to the typical form *striatus*, and former disputing McAtee's identification of it as *lysteri*. Dice (2) and Wood (6) identify the chipmunk of Berrien County, Michigan, as *lysteri*. Cory (1) gives a map showing the ranges of the different forms of the genus. According to it *lysteri* is not found in Michigan. The form in the southern portion of Indiana is *striatus* and the form at the southern end of Lake Michigan is *griseus*. The rest of the northern portion of Indiana is occupied by intermediates between *striatus* and *griseus*. As the flora of the dunes contains many northern forms of plants, and in the absence of a series of chipmunks, one is inclined to refer the dune animal to a northern race, either *griseus* as adopted by Cory or *lysteri* by Dice.

Red squirrel or chickaree (*Sciurus hudsonicus loquax* Bangs): The red squirrel is fairly common in the wooded portions of the dunes. They are often seen running about and frequently heard. Four specimens were secured, a pair of adults caught in traps baited with apples, a nearly mature individual given me by Wilbur Eklund, and a half grown young unable to take care of itself found wandering near our tent. The adult female which was trapped September 27, was nursing, (mammae axillary 1/1, pectoral 1/1, inguinal 2/2=8). As young in two stages of development were secured it may be inferred that at least two broods are raised each year. Measurements of the adult male and female: Total length 320, 320; tail 125, 125, hind foot 46.5, 47 mm.

Western fox squirrel (*Sciurus niger rufiventer* Geoffroy): This handsome squirrel is frequently seen in the wooded portions of the dunes. No specimens were secured. It does not appear to mind civilization so long as trees are abundant. There are a number of them living along some of the well treed streets of South Bend.

Woodchuck (*Marmota monax monax Linnaeus*): Woodchucks are very common almost everywhere in wooded portions of the dunes as judged by their many burrows. The animals themselves are not so frequently seen. Their burrows are never placed on the face of dunes on the lake front and I have never seen anything that might be interpreted as their tracks in the light dry sand of the fore dunes. Immediately after the establishment of wooded dunes their burrows are found either high up or just above the levels of the interdunal meadows and ponds or subdunal swamp. No attempt was made to secure specimens. The species is represented in my collection by a weathered skull picked up near the Furnessville blowout. Hahn (4) says, in southern Indiana the woodchucks "usually retire about the middle of October". The first five days of October 1922 were unusually warm, our Six thermometer recording daily maxima of 78, 84, 80, 80, and 86°F. respectively, after that the weather became cooler though not cold. A woodchuck was seen on October 4 and up to the time of the cooling weather fresh tracks appeared about their burrows. After that date woodchucks were not seen and frequent rains interfered with seeing whether their burrows

had been freshly used. W. D. Richardson says he saw a woodchuck as late as the last of October or first of November, 1922. In the dunes I have never seen any evidence of essential damage to plants attributable to them. They certainly are much less destructive than man. It is a pity they do not show themselves oftener than they do.

Mearn's cottontail (*Sylvilagus floridanus mearnsii* Allen): Cottontails seem fairly common in the region. I have seen them in nearly every locality except the fore dunes. On two occasions I saw cottontails running from the red osier dogwood and fox grapes near our tent as we were returning late in the afternoon. They may have been attracted by the fox grapes which were trailing over the sand. No specimens were secured.

Virginia deer (*Odocoileus virginianus* Boddaert): The Virginia deer has been extinct in the region under consideration for many years. H. W. Leman of Chicago, who is much interested in the dunes and owns a large tract of land along the lake front west of Waverly Beach, says that one of his Chicago friends, now dead, told him that when he was a young man there was excellent deer shooting in the dunes. If his friend were living he would be about 75 years of age. One may conclude from this that deer were fairly numerous in the dunes about 1875. They were probably all killed off shortly after that time. If they persisted for ten years longer the date of their disappearance would be only a few years earlier than the last record for Jasper and Newton Counties, 1890 and 1891 according to Butler (4). Their former abundance in the region is attested by remains which are not infrequently found. In his cottage in the dunes H. W. Leman has a very perfect antler picked up in the sand. Miss Rose Leal of Chicago gave me a nearly complete antler which she had picked up in a blowout. Its length following the convexity from burr to broken tip is 320 mm., circumference just above the burr 85 mm. In a blowout adjacent to our camp I found three fragments of antlers not quite so large. With them were various badly weather-worn bones and two molar teeth. Whether all the fragments came from one animal cannot be said. In another blowout to the west I picked up two molar teeth and portion of metatarsals and metacarpals and vertebrae. With these evident deer bones were a fragment of lower jaw of a member of the genus *Canis*, probably a large dog rather than a wolf and the upper end of the femur of possibly a dog. In a blowout near Waverly Beach F. E. Challis collected numerous fragments of deer bones. At the water's edge when the lake was unusually low I picked up an almost perfect left ramus of a deer's mandible. Part of the symphysis is present but none of the incisor or incisor-like teeth, but the cheek teeth are all in place and essentially perfect. The length of this toothrow (alveoli) is 83 mm. The last molar is slightly worn, the teeth anterior to it moderately so. It is said that in the public library of Gary there is a very complete pelvis of a deer found in the dunes by Boy Scouts.

Mammals Almost Certain to be Found in the Dune Region of Porter County, but Concerning Whose Occurrence There is no Satisfactory Evidence at the Present Time in the Nature of Specimens Collected or Observed.

Little brown bat (*Myotis lucifugus* Le Conte), Say bat (*M. subulatus* Say), brown bat (*Eptesicus fuscus* Beauvois), silver-haired bat (*Lasionyceris noctivagans* Le Conte), hoary bat (*Nycteris cinera* Beauvois), Pennsylvania vole (*Microtus pennsylvanicus* Ord), jumping-mouse (*Zapus hudsonius* Zimmerman), flying squirrel (*Glaucomys volans* Linneaus), gray squirrel (*Sciurus carolinensis* Gmelin).

Existing Mammals Which Probably Occur or Have Lately Occurred in the Dune Region of Porter County.

Star-nosed mole (*Condylura cristata* Linnaeus), long-tailed shrew (*Sorex personatus* Goeffroy,) small short-tailed shrew (*Cryptotis parva* Say), lemming mouse (*Synaptomys cooperi* Baird), badger (*Taxidea taxus* Schreber). The badger was noted by Wood (6) in Berrien County, Michigan, as late as 1917. A. E. Didelot who is quite familiar with badgers from experience in Wyoming and has information of most of the animals trapped about Waverly Beach and Chesterton, knows of none having been taken in the region.

Mammals Not Now Extant in the Dune Region of Porter County, but Whose Remains May Possibly be Found Buried in the Sand or in the Swamps.

Fisher (*Martes pennanti* Erxleben), black bear (*Ursus americanus* Pallas), otter (*Lutra canadensis* Schreber), puma (*Felis cougar* Kerr), Canada lynx (*Lynx canadensis* Kerr), bay lynx (*L. ruffus* Gueldenstaedt), porcupine (*Erethizon dorsatus* Linneaus), varying hare (*Lepus americanus* Erxleben), bison (*Bison bison* Linneaus), elk (*Cervus canadensis* Erxleben).

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REACTIONS TO LIGHT AND PHOTORECEPTORS OF LUMBRICUS TERRESTRIS.

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It is generally known that earthworms are sensitive to light, but comparatively little is known concerning the nature and distribution of the photoreceptors.

It has been shown by numerous workers that worms of this species are negative to all ordinary intensities of light. In fact, the nocturnal habits of these animals indicates that they can distinguish between light and darkness, and since they are nocturnal in habit they must be negative in their normal reactions to light of the intensity of daylight.

Although lights of ordinary intensities cause these animals to react negatively, lights of very low intensities have an opposite effect. When normal worms were exposed to a light of about .00118 meter candle power, which was covered by a yellow glass, the worms were no longer negative but showed a definite majority of positive reactions. These positive reactions to very weak lights are certainly in keeping with the nocturnal habits of these worms.

Injury to the brain by removal, by removal of one lobe, or by severing the circumesophageal commissures, resulted in these worms losing their power to react negatively. In fact, under such conditions these worms are fully as strongly positive as normal worms are negative.

If the ventral nerve cord of an earthworm is severed, as between segments four and five by a slight ventral incision, the animal is now really physiologically double so far as its reactions to light are concerned; the first four segments being definitely negative and those caudal of segment four are definitely positive.

These results show that the seat of negative reactions resides in the brain and when this center is injured or destroyed the worms no longer respond negatively but become positive in their reactions to ordinary lights.

Now let us turn our attention to other experiments in order to discover if possible the regions of the body that are most sensitive to light, for the purpose of determining the distribution and nature of the photoreceptors.

By the use of ordinary illumination it is possible to demonstrate that worms of this species are most sensitive to light in their anterior regions, somewhat less in the posterior and least of all in the middle portions of their bodies.

By means of a strong pinhole light, the prostomium and the three anterior segments were found to be most sensitive, of which the prostomium appeared to be slightly more sensitive than the rest. Although all segments were found to be photosensitive, each segment, with the possible exception of the first three and the last one or two, was most sensitive in the middle portion of the dorso-lateral region. No reactions were obtained by illuminating the mid-dorsal areas except those of the twelve anterior and the three posterior segments. The

"Proc. 38th Meeting, 1922 (1923)."

worms did not react to illumination on the mid-ventral surface except on the three anterior and the last segment.

Some of these conclusions were confirmed by tests made, following the removal of certain anterior segments and certain parts of the nervous system.

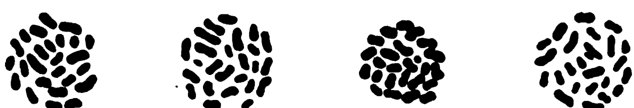
A comparison of the histological structure of the more sensitive with the less sensitive regions, revealed the fact that a rather peculiar type of sense-cell is more abundant in the former than in the latter areas. This indicates that these sense-cells are photoreceptors.

CHROMOSOMAL VARIATIONS IN THE EARWIG, ANISOLABIS ANNULEIPES LUCAS.

W. P. MORGAN, Indiana Central College.

The specimens for the following study were collected in the locality of New Orleans, La. and Mississippi College, Miss. The study, however, was based largely on the Louisiana material. The specimens were identified as *Anisolabis annuleipes* Lucas by A. N. Caudell, Bureau of Entomology, Washington D. C. The gonads were fixed in Flemming and the sections were stained with Haidenhain's hematoxylin and a few were counter-stained with eosin. All the work was done under the direction of Dr. Fernandus Payne to whom the writer is greatly indebted for helpful criticism and advice.

Several workers beginning with Carnoy in 1885 have described the spermatogenesis of the European earwig and there has been much disagreement in the descriptions and explanations of the various authors. Payne[1] reworking the spermatogenesis proves beyond a doubt that many irregularities do exist in this species and in this way accounts for some



1 2 3 4

Fig. 1-4. Spermatogonial metaphase showing 25 chromosomes.

of the disagreement of the preceding workers. Although the following study does not have a direct bearing on these explanations, nevertheless it does definitely show certain irregularities and probably with a more extended study of several species of earwigs we may find that most of the chromosomal irregularities of this whole group of insects will become understandable. The writer is at present working on a comparative study of the spermatogenesis of the earwigs.

Description. The spermatogonial number in *Anisolabis annuleipes* Lucas is 25 (figs. 1, 2, 3, 4). This was shown to be the case by a great many counts of clear metaphase plates.

During the growth period one or more dark staining bodies are seen in the nucleus (figs. 5, 6, 7). By following these bodies during this period and the early prophases it was found that one body very definitely continues as a bivalent chromosome. As shown in figures 8 and 9 the parts of the bivalent are not of equal size. The dark staining body and its changes in the growth period and early prophase is similar to that described by Payne in the European earwig except that he did not find the body bilobed. In the latter part of the prophase this unequal pair of chromosomes, which the body very definitely

[1] Payne, Fernandus. Chromosomal Variations and the Formation of the First Spermatocyte Chromosomes in the European Earwig, Forficula sp. Journal of Morphology, Vol. 25, No. 4.

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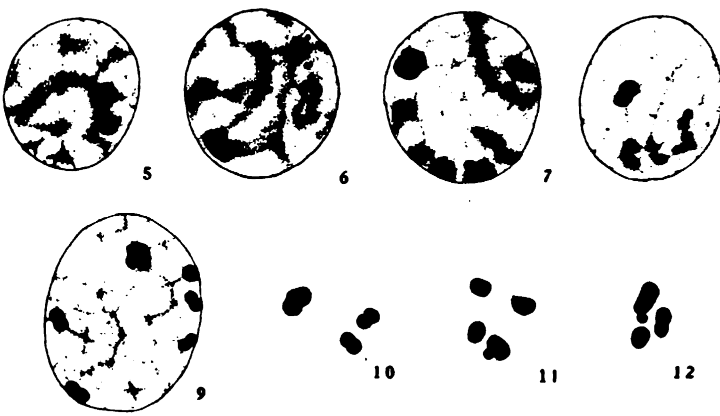
becomes, is seen occasionally to break up into a large bivalent and a small univalent chromosome (figs. 11, 12). The separation of the small univalent from large bivalent seems to take place in only a small percentage of the dividing cells while a condition similar to figure 10 is very often found.

With the spermatogonial count of 25 it would be expected that the metaphase counts of the first spermatocyte division would show 13, but such was not the case except in a small percentage of the counts. By counting only clear metaphase plates it was found that 92 per cent showed 12 chromosomes (figs. 13, 14). The study of the side views of the metaphase division showed clearly that the univalent chromosome did not lie in a different plane from that of the bivalent chromosomes nor did it pass to the pole before the division of the bivalents as has been described in several instances. In a very few of the cells examined it was found that a small univalent chromosome could be seen in the



Figs. 5-12. (5. 6 and 7), Growth period showing dark staining bodies; (8 and 9), prophase, dark staining body becoming unequal pair; (10), later prophase showing unequal pair; (11 and 12), small univalent separating from bivalent chromosome.

side views (figs. 17, 18). This accounts for the small percentage of 13 counts (figs. 15, 16).

The metaphase counts of the second spermatocyte division showed no such irregularity in chromosome behavior as that found in the first spermatocyte division. Of the 513 counts made of this division 280 showed 12 (figs. 32, 33) and 233 showed 13 (figs. 34, 35). A study of the side views of the division showed that all the chromosomes divided normally.

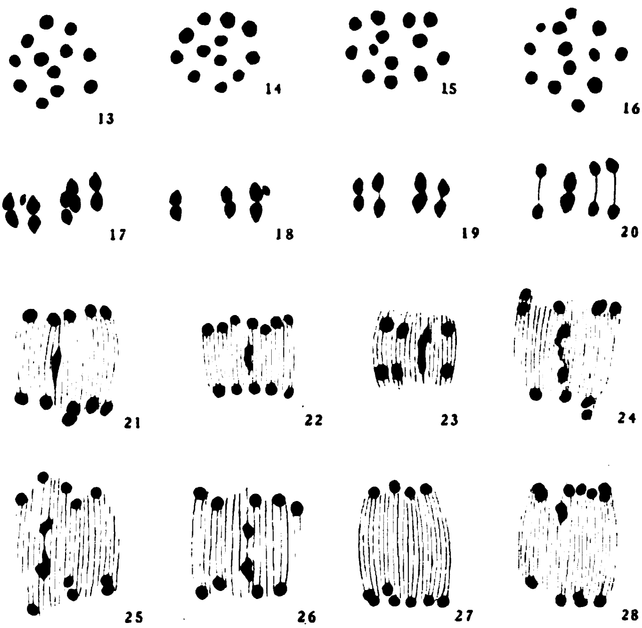
From the above facts it appears that the real problem here would be to account for the disappearance of the univalent chromosome that was present in the spermatogonial metaphase and its reappearance in the second spermatocyte division. The second spermatocyte counts showed nearly equal numbers of twelve and thirteen chromosomes. This is just what would be expected when the spermatogonial number is 25.

In the growth period and early prophase one of the dark staining bodies was seen to give rise to an unequal pair of chromosomes. This

unequal pair passed normally into the metaphase stage. With the condition described by Payne in mind, where the larger end of the unequal pair showed a bilobed appearance, it was thought that some such condition might be found here. A careful study of the side views showed no such condition, however. It was found that a slightly unequal pair did exist and that this pair started to divide shortly after the other pairs. Figures 11 and 12 of the prophase show the unequal pair breaking up into a large bivalent and a small univalent chromosome. Figures 17 and 18 shcw the small univalent chromosome in the metaphase. The separation of the univalent chromosome as shown in the above figures accounts for the normal thirteen count that was found in a small percentage of cases (figs. 15, 16). Another abnormality that was found in the side views of the first spermatocyte division was the large number of lagging chromosomes. This species differs in this respect from the European species in that the lagging chromosomes were found in the first spermatocyte division only, while in the latter they were found to occur in both spermatocyte divisions. One lagging chromosome was found in the second division but this evidence has been disregarded because of the probable pathological condition of the specimen. This pathological condition was quite evident in other cysts of the same testis. The form of the lagging chromosomes was seen to vary a great deal from a single elongated mass to that of a more or less trilobed condition (figs. 21-28). It was noticed as stated above that the unequal pair divided somewhat later than the other pairs. By tracing this unequal pair from the metaphase to the anaphase the evidence seemed to warrant the conclusion that the lagging chromosomes were these unequal pairs that were dividing irregularly. Figure 25 shows an unequal pair dividing into an upper single mass and a lower mass that is somewhat bilobed. Figures 23, 24 and 26 also indicate this condition. Figures 27 and 28 are serial sections of the same cell in anaphase. By counting the chromosomes in both figures the lower part shows definitely 12 chromosomes while in the upper part are 11 chromosomes and the bilobed chromosome that is slightly lagging. If this lagging individual is the unpaired univalent plus one half of the divided bivalent we have, then, 12 chromosomes passing to the lower pole and 13 to the upper. This is just the distribution that would be expected with the 25 chromosomes in the spermatogonial division. That the univalent chromosome becomes attached to one of the autosome pairs causing this lagging in the first spermatocyte division is further evidenced by the condition shown in figures 23 and 26. In figure 23 an enlargement on one side of the lagging chromosome is very noticeable. Figure 26 is a later anaphase than figure 23. Here the lagging chromosome has divided but the parts still lag behind the autosomes. The upper chromosome is much smaller than the lower and the irregular outline of the lower mass resembles the upper part of the lagging chromosome in figure 23. One suggestion the writer might offer to account for these lagging chromosomes is that it is determined by the position of the attachment of the small univalent chromosome to the larger autosomes. When the small chromosome becomes attached so as to adhere to both autosomes the three chromosomes assume the linear arrangement in early

anaphase and later the whole mass is drawn out into the characteristic strand shown in figure 21. Later anaphase show that these lagging chromosome groups finally divide unequally and pass to the poles losing their identity in the condensed mass of chromosomes of the late anaphase (fig. 29).

The above explanation of the lagging chromosomes is not offered to explain a condition of similar appearance found in other forms but applies only to *Anisolabis annuleipes.* The writer does not offer the suggestion to explain the presence of two lagging chromosomes which

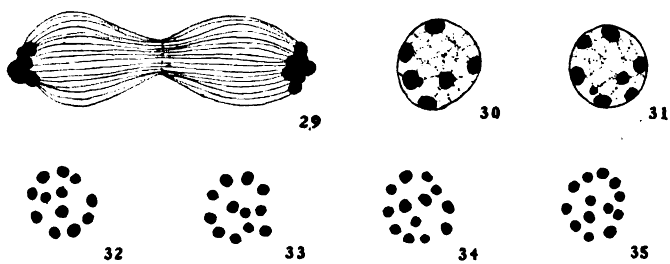


Figs. 13-28. (13 and 14), Metaphase polar view showing 12 chromosomes; (15 and 16), same showing 13 chromosomes; (17 and 18), side views showing small univalent; (19 and 20), side views of unequal pair; (21, 22, 23 and 24), side views of anaphase with lagging chromosomes; (25 and 26), division of lagging chromosomes; (27 and 28), serial section of a cell in later anaphase showing bilobed chromosome.

are only very rarely found in this species. Since the few cells with two lagging chromosomes seemed to degenerate in late anaphase the writer concludes that these cells fail to complete the maturation divisions.

Following the first spermatocyte division the nucleus passes through a short rest period before the second spermatocyte division (figs. 30, 31). A careful study of the nucleus from anaphase of the first to the metaphase of the second spermatocyte divisions was made. During the condensed appearance in the late anaphase the chromosomes could not be traced (fig. 29). In the reorganization of the nucleus the chromosomes separate and remain as distinct bodies distributed through the nucleus until the prophase of the second spermatocyte division. After this

reorganization a chromosome much smaller than the others can be seen. Figure 31 shows this small chromosome. This stage seems to be later than that shown in figure 30 where the small individual lies against the large chromosome. Conditions similar to these figures are very common in the cysts showing the rest stage. No great difference was found in the sizes of the chromosomes in the metaphase plates showing 12 chromosomes (figs. 13, 14) but in figures 15 and 16 showing metaphase plates with 13 chromosomes one small chromosome can be seen. This would indicate that the attached univalent was much smaller than the other chromosomes and this difference in size should make it noticeable at once when it became detached. On the basis of size the small body appearing in the rest period (figs. 30, 31) seems to be the univalent chromosome. Further study shows this small element behaving in the prophase of the second spermatocyte division as the other chromosomes. This seems to warrant the conclusion that the small univalent that disappeared prior to the first spermatocyte division became attached



Figs. 29-35. (29), Late anaphase showing chromosomes in condensed mass; (30 and 31), rest stage between first and second spermatocyte divisions showing very small chromosome; (32 and 33), second spermatocyte metaphase with 12 chromosomes; (34 and 35), same showing 13 chromosomes.

to one of the autosome pairs and remained attached until the reorganization of the nucleus in the telophase of the first spermatocyte.

Since the specimens were collected fairly late in the season some of the testes were filled with mature spermatozoa and many of the others had few cysts with cells in division. Although all the stages described above could be traced in many specimens there were a few that had several cysts in metaphase that permitted a large number of counts per individual. A description of one typical specimen with several cysts in metaphase might be of interest here. Specimen 40 seems to be of interest in this connection. Only one clear count of the spermatogonial metaphase could be made. It showed very definitely 25 chromosomes. The description of the growth period given above could be applied to this specimen (figs. 5, 6 and 8) although very few prophase groups similar to figures 11 and 12 were found. Here all of the 14 clear metaphase counts in the primary spermatocyte showed 12 chromosomes. The one cyst in the rest stage between the first and second spermatocyte divisions showed clearly many stages the close association of the small chromosome and the large one similar to figures 30

and 31. In the secondary spermatocyte there were 69 polar views of the clear metaphase plates. Of this number 37 showed 13 and 32 showed 12 chromosomes (figs. 32, 34 and 35). This is just what would be expected where there were very few cases of the prophase separation of the small univalent and the large bivalent chromosomes (figs. 11 and 12). The metaphase counts alone show very definitely that the univalent chromosome behaves irregularly prior to the second spermatocyte. No lagging chromosomes were seen in this specimen.

The above evidence leads to the conclusion that the small individual seen in the resting stage and early prophase of the second spermatocyte becomes attached to one side of the large chromosome pair sometime between the metaphase of the spermatogonial division and the prophase of the primary spermatocyte. Although this attachment has not been observed it probably takes place very early in the growth period. These attached chromosomes form the larger end of the unequal pair. Occasionally the chromosomes become detached allowing all pairs to divide normally while the univalent chromosome passes undivided to one pole giving the 13 chromosomes in the first spermatocyte metaphase. Nothing can be said with certainty as to the mode of attachment although the small chromosome seems to be plastered to the side of the larger chromosome so as to show no break in the general outline of the mass except for a slight enlargement (figs. 19 and 20). It might be expected that the attachment of the univalent chromosome to one-half of the autosome pair would make a very noticeable enlargement but such was not the case. Figures 17 and 18 show the univalent chromosome unattached but near one of the large autosome pairs. Assuming that the small chromosome was plastered to the upper half of the large bivalent chromosome the resulting mass would not be greater than the larger end of the unequal pairs shown in figures 19 and 20. After the condensed condition in the anaphase of the first spermatocyte division (fig. 29.) the chromosomes separate as individuals from this chromosomal mass and remain separated to divide normally in the secondary spermatocyte. This accounts for the unusual number of 12 chromosomes in the first spermatocyte and the normal number of 12 and 13 chromosomes that appears in the second spermatocyte.

It is interesting to note that the same numerical condition has been found in the distribution of the chromosomes of *Anisolabis maritima* by Kornhauser[2].

[2] Kornhauser, S. I. Cytology of Anisolabis maritima. Abstract of Papers, American Society of Zoologists 1920.

A HYGROTHERMOGRAPH PUZZLE.

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In the course of the investigation of some biological problems it is frequently desirable to secure temperature and humidity records for possible correlation with the behavior of the individuals under observation. At a one man observation station it sometimes happens that the attendant's services are badly needed elsewhere on the particular day, usually Monday, when the record sheets of recording instruments are to be changed. In order to take advantage of such occasions and at the same time have the records continue uninterruptedly, a scheme was

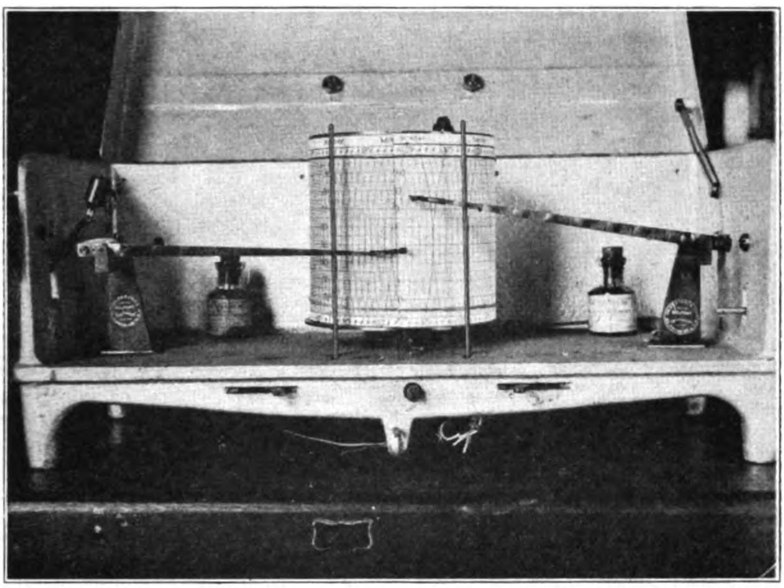

Fig. 1. Hygrothermograph showing the recording pens in position as they pass from the old to the new record sheet without interruption of records.

originated by which the attendant could put on the new record sheet before his departure and so arrange it that the graph would continue from the old to the new sheet on Monday without further attention.

On the day of departure the clock is wound and a new record sheet is placed in position in the usual manner. Most of the used portion of the old sheet is folded under so that the new sheet is left exposed until the same day of the following week. The edge of the unused portion of the old sheet is folded snugly under and arranged so that the respective time arcs and horizontal percentage or degree lines are coincident with those of the new sheet. (See Fig. 1.)

The bar which usually is furnished to hold the record sheet in place can very well be replaced by strong elastic bands at the top

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and bottom of the cylinder. These have been found to hold the sheets more snugly to the cylinder in most cases than does the bar. The recording pens are then set to continue the graphs on the old sheet and when it is finished they pass on to the new sheet in their proper respective positions. When the attendant returns, the old record sheet is removed and the new one is left in place for records until the next regular time for change.

By actual test with the record sheets thus arranged and snugly adjusted to the cylinder, the acceleration caused by the extra thickness of paper due to the folding of the old record sheet, was found to be scarcely, if at all perceptible even for the accumulation of a period of three days.

NAGANA (*TRYPANOSOMA BRUCEI*): THE COURSE OF THE DISEASE IN LABORATORY ANIMALS WHEN INJECTED WITH CULTURES GROWN *IN VIVO* AND *IN VITRO*.

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Nagana, or Tsetse fly disease, as it is correctly called, is due to a specific trypanosomal parasite. It occurs naturally in many parts of Africa, and its causative agent, which was discovered by Bruce in 1894, bears the scientific name of *Tryanosoma brucei.*

Normally the parasite exists in the blood of certain animals which apparently have a marked tolerance for it, thus serving as its natural source of infection.

Most mammals are susceptible to Nagana with the exception, however, of man. The parasite can easily be perpetuated *in vivo* by resorting to the ordinary laboratory methods of inoculation. And also since the trypanosome can be cultivated *in vitro* upon blood agar medium, as Novy and MacNeal[2] first demonstrated in 1903, it lends itself ideally for experimental work. It is very interesting not only because it is a disease of distant Africa and due to a special type of parasite, but also because of the fact that it gives to a trypanosomiasis occurring in very distinct forms depending primarily upon the species of the animal and the virulence of the organism.

The source of the strain of *Trypanosoma brucei* used in our experiments is from an infected dog sent by Bruce to England in November, 1896, and it was this parasite which Novy and MacNeal used in their cultivation experiments.[3]

There are three distinct varieties of the disease:

First, the acute type which occurs in the rat, mouse, field mouse (Arvicola), marmot, hedgehog, dog, cat, squirrel and monkey.

Second, the subacute type which develops in the rabbit, guinea-pig, field mice (*Mus sylvaticus, Arvicola arvalis*), garden mouse (*Eliomys quercinus*), equine, and pig.

Third, the chronic variety which occurs in cattle, goats, sheep, geese and fowls.

Table I lists some of the animals susceptible to Nagana.

In an acute infection, the trypanosome makes its way into the blood in from one to several days. Following this infection the number of parasites usually increase constantly and regularly until the death of the host, which may occur in a few days, or a week, or even longer.

The subacute course of the disease is quite different for while the parasites do not appear in the blood as soon as in the acute form their development is not rapid and continuous for they may practically dis-

[1] Contribution from the Bacteriological Laboratory, Purdue University, Lafayette, Indiana.

[2] Jour. Amer. Med. Assn., 1903, 41, p. 1266; Jour. Infect. Dis., 1904, 1, p. 1.

[3] This work was made possible through the kindness of Dr. F. G. Novy, Professor of Bacteriology, University of Michigan, from whom trypanosomal blood was obtained.

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appear and reappear and repeat this activity several times before they may or may not become extremely numerous shortly before the death of the animal. The organism may be first seen in the blood stream in about two or more days and the extent of the disease may be from less than two to many weeks.

TABLE I. Showing the Results of Different Animals Infected with Nagana.

Animal	Method of Injection	Period of Incubation Days	Duration Days
Rat	S. C.	2	3½–5½
	I. P.	Less than 1	2½–3
Mouse	S. C.	2	3½–5½
	I. P.	Less than 1	2½–3
Field mouse (*Arvicola arvalis*)	S. C.	2–6	4–12
(*Mus sylvaticus*)	S. C.	8	30
Dog	S. C.	4–6	14–26
	I. P.	2–4	6–14
Cat	S. C.	4–5	19–44
	I. P.	2–4	14–28
Guinea-pig	S. C.	2–7	7–78
	I. P.	1–3	5–61
Rabbit	S. C.	6–8	13–89
	I. P	2–3	10–75
Horse	S. C.	7–8	15–92
	I. P.	4–5	8–49
Ass	S. C.	7–8	15–92
	I. P.	4–5	84
Cattle	S. C.	5	Months—may recover
Sheep	S. C.	3	6½ months—may recover
Monkey (Macacus)	S. C.	4	15
Hedgehog	S. C.	4	13–17

S. C.—Subcutaneous inoculation.
I. P.—Intraperitoneal.

In the chronic infection the trypanosome appears as a rule several days after the inoculation and then after running a very irregular course for months, during which time only very few organisms are usually observed, they may disappear entirely and the animal recovers.

Technique of Studying Trypanosomes in Living Condition.—Since the parasites are usually present in the blood stream the most convenient method of obtaining blood is employed. When the organisms are numerous in the blood a very small amount will suffice to reveal their presence.

In case of the rat and mouse the tail is clipped while in that of the dog, rabbit and guinea-pig a blood vessel in the ear may be pricked or a small incision made in the ear. A drop of the fluid is placed on a slide or cover-slip and by gentle pressure a one layer preparation, which is usually desirable, is obtained. At times, however, when the parasites are very scarce a heavy preparation will aid in identifying their presence by the movement of the red blood cells.

This simple preparation is excellent for making a hasty examination but currents are soon set up in the liquid due to desiccation, thus rendering further examination quite impossible. If longer observations are desired the preparation may be rimed with paraffin or a hanging-drop or the Ranvier slide preparation resorted to.

When, however, the trypanosomes are extremely scanty in numbers diagnosis cannot be made by this simple procedure, although repeated examinations are continued on successive days. In such cases the animals are bled for a larger amount of blood which, after defibrinating or chemically treating to prevent coagulation, is centrifuged at high speed. The parasites, if present, will be found just above the red blood cells.

The blood of the suspected animal may be inoculated into very susceptible animals and in turn their blood may be examined for trypanosomes. Stained blood smears may aid in establishing the development of trypanosomiasis.

At times the examination of the oedematous fluid or serous exudate from the lesions will reveal the presence of the parasite.

Inoculation of Animals with Cultures Grown in vivo.—Since in this work the common laboratory animals were used, as the rat, mouse, dog, rabbit and guinea-pig, the course of the disease will be described as it occurred in these animals.

Experiments with rats.—When a very susceptible animal as the rat or mouse are injected with the trypanosomal blood they, of course, succumb from the acute variety of Nagana. The period of incubation, that is the first appearance of the trypanosome in the blood stream after the inoculation, is usually 18 to 24 hours. From this time on the number of parasites increase at an enormous rate until death, which occurs in two and a half to five days, depending largely upon the virulence of the organisms, numbers injected and their avenue of introduction into the animal. Just before the fatality which is always certain, the organisms are as numerous as and even greater than the number of red blood cells.

If rats or mice are inoculated with trypanosomal blood from other animals such as the guinea-pig or rabbit, the virulence of the parasite for the former animals is somewhat attenuated as is evidenced by a slightly longer period of incubation, usually two to three days, and death does not occur until six or eight days. However, After the organism makes its appearance in the blood stream its development is about the same as that in a rat or mouse which had received the trypanosome from the blood of an animal of the same species.

In a period extending over nine years in which over 1,200 rats were used, the minimum period of incubation was about ten hours and

the maximum 74 hours, while the minimum duration of the disease was 20 hours and the maximum about 140 hours. The average period of incubation was about 23 hours and the average duration 80 hours.

During the course of the disease these animals seem to be normal except possibly during the last day when they may be more or less drowsy. There are no morbid symptoms or lesions and both rats and mice may or may not die with convulsions. They are, however, excitable and if excessively annoyed convulsions usually occur just previous to death.

Experiments with dogs.—Probably the dog is the most susceptible animal, excepting the rat and mouse. If the duration of trypanosomiasis is short, only a week or two, the development of the parasites is rapid and regular. On the other hand, if the disease runs along for three or more weeks there may be an increase in the number of trypanosomes at first, followed by an abrupt decrease, but at no time does the parasite entirely disappear from the blood stream. In this respect it is unlike the subacute or chronic variety of the disease. There may be several such relapses followed usually by a marked increase before death.

In the four dogs used in the experiment (table II) the minimum period of incubation was two to four days, the maximum seven to nine days; the minimum duration of the disease six days and the maximum duration 26 days. The average period of incubation was 4.3 to 6.3 days while the average duration was 16.3 days. The animals seem to become extremely weak and there is a loss in weight. There is marked hypertrophy of the inguinal glands, the vision appears to be disturbed and there is a rise in temperature.

Inoculation with Cultures Grown in vitro.

The medium employed to obtain this strain of *Trypanosoma brucei* was a modification of the original Novy and MacNeal blood agar. The isolation was obtained by using a pea and bean blood agar or a serum agar as described by the author in 1916.[4] The parasite after becoming well established outside of the animal was perpetuated upon blood agar medium.

TABLE II. Inoculation of Dogs with Cultures Grown *in vivo*.

No. of Dog	Weight, Gm.	Period of Incubation, Days	Death, Days	Weight After Death Gm.
1	5500	7–9	26	5000
2	3210	4–6	20	2970
3	3050	4–6	13	2950
4	3090	2–6	6	3090
Average	3712.5	4.3–6.3	16.3	3502.5

[4] Proceedings of the Ind. Acad. of Sci. 1916. pp. 264-271.

Experiments with rats.—From the foregoing it will be noted that the rat always succumbs from the acute form of the trypanosomiasis when inoculated with the blood strain of the parasite. When, however, it is injected with cultures grown *in vitro* the disease may be drawn out to the subacute and in some cases to the chronic variety of the disease. This is apparently due to the generation and age of the culture, temperature at which it was incubated and the number of trypanosomes introduced into the animal.

Rats inoculated with generation one of *Trypanosoma brucei* show variable results primarily due to the age of the culture. The possibility of the original blood survival being present is not taken into consideration although this may be actually the case. They have been observed but proven to be avirulent.

Infection can usually be produced when cultures of that generation are injected that are 6 to 11 days old. Cultures older than that are non-infective.

The period of incubation, as well as the duration of the disease varies. The former lies between four to eight days and the latter may be from 8 to 14 days. Whereas, if generation two, seven days old, which is the time of its maximum growth, is injected the period of incubation is three to seven days and the time of death is seven to ten days. The variations in the period of incubation and in the duration of the disease that have been noted when rats are injected with generation two are even more irregular when inoculations with subsequent generations are made. The higher the generation the greater the variations. Thus, the average period of incubation in rats receiving generation two is 4.6 days and death occurs in an average of 8.9 days.

Rats inoculated with subsequent generations gradually show a longer period of incubation and the time of death is deferred. With generation 40, the former was 12 to 13 days and the latter was 21 days, although with generations 50 to 57 and 61 the organism seems to have become temporarily exalted. The rats receiving the culture of these generations showed periods of incubation varying from five to nine days. In the rat receiving a seven day culture of generation 89 the parasites were present in the blood in six days and the animal did not die until the 94th day. Again, in the case of generation 154 the period of incubation was eight to ten days and death did not occur until on the 126th day. With generation 190 the rat became infected on the sixth to seventh day and died on the 78th day.

This variation seemed especially more pronounced if the cultures were incubated 14 or even 21 days before inoculations were made. This is nicely shown with generation 85. The period of incubation when a seven day old culture was used was six days, death occurred on the 41st day. If the age of the culture is 14 days the trypanosomes appear in the blood of the rat at about the same time (seven days) but the animal did not die until on the 84th day. And if a 21 day old culture of the same generation was used the period of incubation was 8 to 11 days with death coming on the 51st day. In one exceptional case, that of a 21 day old culture of generation 93, the rat became infected be-

tween the 11th and 14th day and after having the disease for 250 days the animal died on the 265th day.

In all cases where the cultures were set aside for 28 days the trypanosomes became so attenuated and scarce that no infection followed their injection.

These results lead one to conclude that the higher the generation of the organism the greater its attenuation and consequently the longer the duration of the disease. However, like in all experiments of this kind the individual susceptibility of the animal plays an important rôle. Thus, of two rats inoculated with a seven day old culture of generation 154 the duration of the disease in one case was 116 days and in the other it was only ten days. A rat receiving a seven day old culture of generation 85 became infected on the sixth day and died 35 days later. A single inoculation with a 14 day old culture gave a period of incubation of seven days and death occurred on the 84th day, while a rat which suffered from the infection with a 21 day old culture of the same generation (85) showed an 8 to 11 day period of incubation and death resultêd on the 51st day.

As in the case of rats becoming infected with the blood strain of the parasite, those that succumb from the blood agar strain, no matter how long or short the duration of the disease, seemed invariably not to develop the common symptoms of Nagana, such as fever, oedema and anaemia.

Experiments with mice.—It has been shown that mice, like rats, when inoculated with trypanosomal blood develop the same type of the disease and as would be expected they respond in the same manner when injected with the test-tube strain. Of 14 mice inoculated intraperitoneally with seven day cultures of generations 143, 144, and 145, the minimum period of incubation was four to six days and a maximum of 8 to 12 days, an average of about 6.4 to 8.6. The minimum time of death was nine days, the maximum 23 and the average about 13.7 days, as will be observed in table III. And, again, like the rat, the mouse shows none of the characteristic symptoms of the disease.

TABLE III. Inoculation of Mice with Cultures of *Trypanosoma brucei* Grown *in vitro.*

Generation	Period of Incubation, Days	Death, Days	Generation	Period of Incubation. Days	Death, Days
143	5–6	18	144	8–10	14
143	5–6	13	144	8–10	12
143	7–8	17	145	6–8	14
144	4–6	9	145	6–8	14
144	4–6	15	145	8–12	14
144	6 8	12	145	8 12	14
144	6–8	23	145	8–12	13
Average				6.4	8.6

Note: Each mouse received an intra-peritoneal inoculation with varying amounts of a seven day old culture.

Experiments with dogs.—Of the four dogs inoculated with varying amounts of cultures of the trypanosome, which had been cultivated approximately three years *in vitro*, three died of Nagana.

One dog, after receiving five intra-peritoneal injections, each of ten tubes, of generations 140, 141, and 142 in 16 days became infected two days after the last inoculation, or 18 days after the first. After a rapid increase in the number of parasites the dog died on the 44th day.

The second dog received a single injection of ten cultural tubes of generation 144. Unlike the first and third dogs (table IV), this animal developed a typical chronic course of the disease after a period of incubation of only eight days. The parasites were not numerous but once (ten per field) and usually present to the extent of one or two per field with frequent intermissions. Death did not occur until on the 127th day.

The third dog received but one culture and showed trypanosomes ten days afterwards. He died nine days later of the acute infection following severe sickness.

The fourth dog received one-tenth of a culture and did not show parasites in its blood at the end of 39 days when he died.

TABLE IV. Dogs Inoculated with Culture Grown *in vitro*.

No. of Dog	Weight, Gms.	Generation	Amount Injected, Tubes	Period of Incubation. Days	Death, Days
1.	8700	140–141	5x10	2–18	44
2.	2950	142–144	10	8	127
3.	2900	147	1	7–10	19
4.	2600	147	1/10	No infection	39

Inoculation of Rabbits with Cultures Grown in vivo.—Rabbits inoculated with this strain of the trypanosome usually show a period of incubation of from two to five days but sometimes the organisms are not seen by the ordinary methods of examination until on the seventh to ninth day, or in very refractive animals as late as the tenth day or even much longer (31 to 49 days in a few of the exceptional cases where the animals received very small amounts of the infective material).

Also, depending upon the susceptibility of the rabbit, the duration of the disease varies greatly. Death may occur as early as ten days or it may be deferred as long as two and a half to three months. It will be seen in table V that the average period of incubation is 8.4 to 11.9 days, while the average duration of the disease is about 40 days. The number of trypanosomes to be found in the blood of these animals is usually very few and remains so even up to the time of death. The animals run an irregular course of fever and usually show oedematous swellings which may be marked, blepharo-conjunctiva, ccryza, ulceration of the skin and alopecia.

TABLE V. Rabbits Inoculated with Cultures of *Trypanosoma brucei* Grown *in vivo*.

No. of Rabbit	Period of Incubation, Days	Death, Days	No. of Rabbit	Period of Incubation, Days	Death, Days
2.7	9–10	31	1.104	24–31	75
16.11	7–9	29	6.112	10–17	60
17.11	9–10	37	1.119	9–13	44
2.20	5–7	29	10.123	7–9	35
10.28	7–9	41	2.128	7–9	42
1.36	4–7	37	5.129	5–7	21
13.44	6–7	52	2.130	9–13	58
2.46	2–5	17	1.141	13–17	49
2.47	7–9	21	16.150	19–23	64
1.54	5–7	20	1.152	42–49	90
6.64	2–3	10	8.165	7–9	32
17.64	4–5	31	8.168	7–9	39
15.65	4–5	34			
Average.....	....	....	....	8.4–11.9	39.9

TABLE VI. Rabbits Inoculated with Single and Multiple Doses of Ten Tubes Cultures.

No. of Rabbit	Generation of Culture	Amount Injected, Tubes	Period of Incubation, Days	Death, Days	Remarks
1	144	10	....	....	Alive 98 days
2	145	10	....	....	Alive 95 days
3	145	10	....	....	Alive 122 days
4	145	10	....	....	Alive 111 days
5	146	10	....	13	....
6	147	10	....	....	Alive 203 days
7	148	10	66–70	....	Alive 308 days
8	145–149	10x10	....	....	Alive 95 days
9	145–149	10x10	17–49	58	....
10	145–147	4x10	1–12	....	Alive 518 days
11	146–151	10x10	....	....	Alive 110 days
12	146–151	10x10	....	....	Alive 205 days
13	146–151	10x10	....	....	Alive 205 days

Inoculation of Rabbits with Cultures Grown in vitro.—While rabbits suffer from the subacute type of Nagana when infected with the blood strain of the parasite the same does not hold true when the organism has been cultivated upon blood agar for many months.

Rabbits were not inoculated with early isolations of the trypanosomes. Seven rabbits were injected intraperitoneally with the contents of ten tubes of generations 144 to 148, inclusive, and of this set only one showed the presence of trypanosomes in its blood on the 70th day and again ten days later at which time further examinations were negative.

Out of six rabbits, each receiving multiple ten tube doses, two developed trypanosomiasis of which one proved fatal as table VI shows. Rabbit number ten, which received four bi-weekly injections of ten tubes each, revealed the presence of a small number (one per field) of trypanosomes in its blood 12 days after its first inoculation. The number of parasites increased to four per field on the 14th day and then disappeared until on the 27th, 37th, 44th and again on the 126th day when only a single individual was noted in each examination. This animal showed no symptoms of Nagana more than 500 days after its inoculation and was pronounced as recovered.

Rabbit number nine after receiving ten bi-weekly doses of ten tubes each also developed Nagana on the 49th day after the first injection or 17 days after the last injection. At this time but one trypanosome was found but 7 days later ten parasites per field were observed and two days later death occurred. This animal developed the characteristic symptoms of the disease.

Inoculation of Guinea-pigs with Cultures Grown in vivo.—The variation of the disease which has been noted in the rabbit is also markedly borne out in the case of Nagana in guinea-pigs. The parasites do not increase in numbers regularly or rapidly but they may disappear and reappear several times and finally, usually just before death, may be numerous in the blood stream. The disease, generally speaking, runs a more regular course and the organisms are more plentiful than in the case of the rabbit. Nagana is always fatal for guinea-pigs with a period of incubation from two to four or even as high as eight days, the average being a little less than four days when intraperitoneal injections are made and about five days when subcutaneously inoculated. The average duration of the infection is approximately 40 days.

Out of some 600 guinea-pigs examined the shortest period of incubation was 24 hours and the longest eight days. The duration was variable being from seven to 66 days. In the typical course of the disease and also when the infection borders the chronic variety, the guinea-pigs have more or less constant fever and develop conjunctiva which may be purulent and always alopecia which is usually marked especially along the back, around the anus and eyes. Some of the animals become very anaemic.

Inoculation of Guinea-pigs with Cultures Grown in vitro.—Guinea-pigs, like rabbits, because of their refractoriness, develop at best a chronic infection if the parasite has been out of the animal body for several years or the organism has entirely lost its virulence for these

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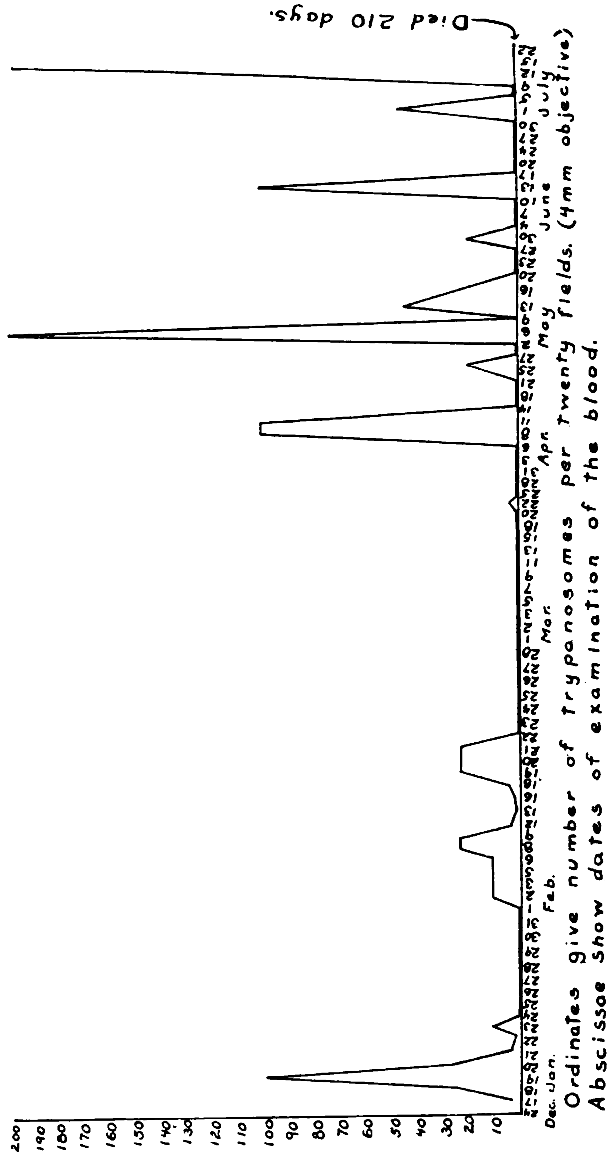

Fig. 1. Graph showing variation in the number of trypanosomes in guinea pig number 5.190 (taken from table VIII), from date of inoculation till death. Animal was inoculated with ten tubes of generation 140.

animals but may be still pathogenic for rats, mice and dogs. *Trypanosoma brucei* if not under artificial cultivation for too long a period will infect guinea-pigs although the period of incubation and the duration of the disease is prolonged, as shown by guinea-pig 16.94 (Table VII). In this case the period of incubation was 14 to 15 days and death did not occur until on the 59th day. On the other hand of 21 animals inoculated each with one tube of generations 133 to 153, inclusive, failed to contract the disease.

It was only when the contents of ten or a multiple of one or ten tube doses were injected that a small per cent of the animals became infected, and in each case the period of incubation and the duration were markedly prolonged as shown in table VII. Thus, also demonstrating that the parasite was not wholly avirulent for the guinea-pig. Since no infection followed by the inoculation of a single cultural tube of the trypanosome in its 105th or later generation, the effect of much larger amounts of the parasites were tested out. Animals were inoculated with ten, 100, ten multiple injection of one, and ten multiple of ten tube doses of the cultural material with surprisingly few infections resulting.

Ten Tube Inoculation.—Only four out of 60 guinea-pigs or six and two-thirds per cent became infected after inoculation with ten culture tubes of generation 133 to 153, inclusive. The minimum period of incubation and duration of the disease was 18 and 50 days, respectively, as compared to the maximum of 40 and 210 days. The average period of incubation for the four diseased animals was 28½ and the average duration 117¾ days.

Course of the Infection.—The courses of the disease in these animals was interesting and since they were more or less alike and were very characteristic of the typical chronic variety of Nagana, the description of the disease of one of these animals, that of number 5.190, will be taken up in detail.

TABLE VII. Showing the Positive Results Obtained in Guinea-pigs by Inoculations with Ten or More Cultures.

No. of Guinea-pig	Generation	No. of Tubes Injected	Period of Inoculation, Days	Death, Days
16.99	40	1	14–15	59
4.190	140	10	39–40	50
5.190	140	10	21–24	210
5.147	146	10	14–18	53
6.147	146	10	28–32	158
6.68	133–139	10x1	51–92	268
5.105	136–144	10x10	7–70	104

The parasite was first seen (one twentieth per field) in the blood stream of the guinea-pig 24 days after it had received a ten culture tube dose. During the next six days trypanosomes were present although for the greater part very few in numbers. The organisms then disappeared and were not again noted until on the ninth examination after which the following 12 examinations were positive. The next 23 examinations did not reveal the presence of the parasite except in one instance when but a single individual was noted. After being present fairly numerous (five per field) in the blood stream for two days, the next three consecutive examinations were negative only to be followed by a positive observation and again by an intermission. The next examination showed the organism in greater numbers (ten per field) than in any other previous examination, however, upon the following examination the parasite had again disappeared. This was followed by five positive findings and four intermissions and the animal died on the 210th day.

Out of the 82 examinations made after the trypanosome was first observed, 32 were positive and 50 were negative during which time there were 11 positive periods and ten relapses. At no time during the course of the trypanosomiasis did the parasite exceed 10 per field which was noted but twice. Their scanty numbers, however, were characteristic as will be noted in figure 1.

One Hundred Tubes Inoculations.—Of four guinea-pigs receiving such injections with generations 141 and 142 no infections followed. One would naturally conclude that if a small percentage of the animals became infected when inoculated with a 10 tube dose that surely at least in a few instances infection would follow if the material inoculated was tenfold.

Ten Inoculations of One Tube.—Six animals were used for this test and received generations 133 to 139 out of which one revealed the presence of the trypanosome in its blood at the end of 92 days after its first inoculation or 51 days after its last. It lived for 268 days never showing more than 10 parasites per field and that but once. During the greater part of its existence the blood stream was free from organisms and, as a matter of fact, although examined twice a week the trypanosomes were observed but five times.

Ten Inoculations of Ten Tubes.—Animals thus inoculated again showed marked variation as to infectivity with the parasite. One of the eight guinea-pigs which received a multiple of ten culture tube dose developed a very chronic form of Nagana. Trypanosomes were first seen in its blood seven days after the last or 70 days after the first injection and as in the case of the previous guinea-pig the organisms were only observed six times during the trypanosomiasis which lasted for ten days.

SUMMARY.

Nagana manifests itself in three distinct types: the acute; the subacute and the chronic.

The virulence of the trypanosome; its avenue of entrance into

the animal body; the number of parasites injected and the susceptibility of the animal plays an important rôle as to the variety of disease that ensues.

The behavior of the parasite in the animal body is noted by examinations of the blood.

The trypanosome is slightly attenuated when it passes through heterogeneous species.

Cultures of generation one usually infect when incubated from 6 to 11 days while longer incubation renders the culture avirulent.

Cultures of higher generations will infect after 21 days of incubation but they are avirulent after 28 days.

The greater the generation the more marked is the variation in the duration of the disease.

Rats, mice and dogs succumb from the acute type of Nagana when inoculated with trypanosomal blood.

The trypanosome multiplies with marked rapidity and regularity in rats and mice while this is not true in dogs, rabbits and guinea-pigs when infected with the blood type of the parasite.

Rats, mice and dogs suffer from the subacute variety of the disease when inoculated with the *in vitro* strain of the trypanosome.

Rabbits and guinea-pigs develop sub-acute and chronic Nagana when infected with the artificially cultivated parasite.

Rats and mice never develop symptoms of Nagana while dogs, rabbits and guinea-pigs usually do.

Nagana is always fatal to rats, mice, dogs and guinea-pigs while in some cases rabbits may recover, apparently spontaneously.

Rats, mice and dogs are still susceptible to the *in vitro* culture while only a small percentage of the rabbits and guinea-pigs become infected after receiving enormous doses of this parasite.

THE USE OF CLARK AND LUBS INDICATORS FOR THE DETECTION OF ACID PRODUCTION BY THE COLON-TYPHOID GROUP.

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The incorporation, into a medium, of heat resisting indicators is one of the common methods practiced for detecting and determining acid production by bacteria.[1] Clark and Lubs indicators lend themselves especially well to this kind of work because they are heat resisting; they do not inhibit bacterial growth; they resist the action of bacteria; and with a number of them, the virage point is at or near the acid concentration of ordinary stock media. The purpose of the following experiments was to differentiate between the various members of the colon-typhoid group by means of their action on various sugars. No attempt was made to measure the amount of acid produced in each case.

The medium used was a 3 per cent nutrient agar made with .3 per cent Liebig's beef extract, 2 per cent Difco peptone and .5 per cent sodium chloride. The ingredients were mixed and autoclaved at ten pounds for one hour, filtered and the reaction adjusted to slight pink to phenol red (Ph=6.8—7.5). Then the bulk was divided into workable portions and .1 per cent of the desired sugar added to each. This was further divided into three portions and .002 parts of indicator added to each portion. The prepared media was then tubed, sterilized in the autoclave at ten pounds for ten minutes and slanted. Care was taken in slanting to allow for a butt in each tube of at least one inch below the bottom of the slant.[2] After solidification the tubes were ready for inoculation.

The indicators used were brom cresol purple, brom thymol blue, and phenol red. The dyes were all made up in 1 per cent alcoholic solutions which were used for stock solutions. In making dilutions .1 cc. of this 1 per cent stock solution was added to a graduate and media poured into it up to the 50 cc. mark. This gave a dilution of 1 part of dye to 2,000 parts of media. By this method the dye readily mixed with the media and did not require further mixing.

The sugars included dextrose, lactose, sucrose, maltose, raffinose, mannose, dulcitol, xylose, rhamnose, arabinose, levulose, and galactose. All these sugars went into solution very readily if added directly to the hot medium. Some of these are classified as rare sugars and would not be practicable for class room work if used in 1 per cent quantities.

The cultures used were the stock cultures used for laboratory work including *B. coli*, *B. typhosum*, *B. dysenteriae*, *B. paratyphosum* A,

[1] H. R. Baker. Substitution of B.T.B. for Litmus in Routine Laboratory Work. Jour. Bact. Vol. VII. 2.

J. Bronfenbrenner, M. J. Schlesinger and D. Soletsky. On Methods of Isolation and Identification of the Members of the Colon-Typhoid Group of Bacteria. The Study of Bactericidal action of C. R. Indicator. Jour. Bact. Vol. V. 1.

[2] H. J. Conn and G. J. Hucker. The Use of Agar Slants in detecting Fermentation. Jour. Bact. Vol. V. 4.

B. paratyphosum B, and *B. enteritidus*. These cultures were carried on stock agar and transferred every twenty-four hours till ready for use.

Inoculations were made in duplicate tubes with a straight platinum wire, inoculating the surface of the slant first and then making a stab in the butt from the bottom of the slant to the bottom of the tube. In reading the tubes the slant and stab were read separately. The stab gave the acid production under anaerobic conditions while the slant gave the acid change under aerobic conditions.

All tubes were incubated at 37° C. for 24 hours.

The following tables give the results obtained.

TABLE 1. 24 Hour Growth. .1 Per cent Arabinose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	yellow	yellow	yellow
	Butt	Color	yellow	green	yellow	yellow	yellow	yellow
		Gas	+	—	—	+ +	+	+ +
B. C. P.	Slant	Color	purple	purple	purple	yellow	yellow	yellow
	Butt	Color	yellow	purple	purple	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ +	+ +
P. R.	Slant	Color	pink	pink	pink	yellow	yellow	yellow
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +

TABLE 2. 24 Hour Growth. .1 Per cent Dextrose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	yellow	yellow	yellow	yellow	yellow	yellow
	Butt	Color	yellow	green	green	yellow	yellow	green
		Gas	+	—	—	+ +	+ +	+
B. C. P.	Slant	Color	yellow	yellow	purple	yellow	yellow	yellow
	Butt	Color	red	purp'e	purple	red	yellow	purple
		Gas	+	—	—	+ +	+ +	+
P. R.	Slant	Color	yellow	yellow	yellow	yellow	yellow	yellow
	Butt	Color	yellow	pink	pink	yellow	pink	pink
		Gas	+	—	—	+ +	+ +	+

TABLE 3. 24 Hour Growth. .1 Per cent Dulcitol.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	green	green	green	green	green	green
		Gas	—	—	—	—	+	+
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	—	—	—	—	+	+
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	pink	yellow	yellow
		Gas	—	—	—	—	+	+

TABLE 4. 24 Hour Growth. .1 Per cent Galactose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B T. B	Slant	Color	green	yellow	yellow	green	yellow	yellow
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ +
B. C. P.	Slant	Color	purple	yellow	green	purple	yellow	yellow
	Butt	Color	yellow	yellow	purple	red	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ +
P. R.	Slant	Color	pink	yellow	yellow	yellow	yellow	yellow
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ + +

TABLE 5. 24 Hour Growth. .1 Per cent Lactose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T B.	Slant	Color	yellow	green	green	green	green	green
	Butt	Color	yellow	green	green	green	green	green
		Gas	+ +	—	—	—	—	—
B C. P.	Slant	Color	yellow	purple	purple	purple	purple	purple
	Butt	Color	yellow	purple	purple	purple	purple	purple
		Gas	+ +	—	—	—	—	—
P R.	Slant	Color	yellow	pink	pink	pink	pink	pink
	Butt	Color	yellow	pink	pink	pink	pink	pink
		Gas	+ +	—	—	—	—	—

TABLE 6. 24 Hour Growth. .1 Per cent Levulose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	yellow	green	yellow	green	green
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +
B. C. P.	Slant	Color	purple	yellow	purple	yellow	purple	purple
	Butt	Color	yellow	yellow	purple	yellow	yellow	yellow
		Gas	+ + +	—	—	+	+ + +	+ + +
P. R.	Slant	Color	pink	yellow	pink	yellow	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +

TABLE 7. 24 Hour Growth. .1 Per cent Maltose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	yellow	green	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	yellow	yellow	purple	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ + +	—	—	+ + +	+ + +	+ + +

TABLE 8. 24 Hour Growth. .1 Per cent Mannose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	yellow	yellow	green	green	green
		Gas	+	—	—	+	+	+
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	pur, le	yellow	purple	purple	purple	green
		Gas	+	—	—	+	+	+
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	grey	grey
		Gas	+	—	—	+	+	+

TABLE 9. 24 Hour Growth. .1 Per cent Raffinose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	—	—	—	—	—	—
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	—	—	—	—	—	—
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	grey	grey
		Gas	—	—	—	—	—	—

TABLE 10 24 Hour Growth. .1 Per cent Rhamnose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	green	green	green	yellow	yellow	yellow
		Gas	+	—	—	+	—	+
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	green	purple	purple	green	purple	yellow
		Gas	+ +	—	—	+ +	—	+ +
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+ +	—	—	+	—	+ +

TABLE 11. 24 Hour Growth. .1 Per cent Sucrose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	green	yellow	lt. green	green	green	green
		Gas	—	—	—	—	—	—
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	—	—	—	—	—	—
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	grey	grey
		Gas	—	—	—	—	—	—

TABLE 12. 24 Hour Growth. .1 Per cent Xylose.

			Colon	Typhoid	Dysentery	Para A	Para B	Enteritidus
B. T. B.	Slant	Color	green	green	green	green	green	green
	Butt	Color	yellow	green	green	green	yellow	yellow
		Gas	+	—	—	—	+	+
B. C. P.	Slant	Color	purple	purple	purple	purple	purple	purple
	Butt	Color	purple	purple	purple	purple	purple	purple
		Gas	+	—	—	—	+	+
P. R.	Slant	Color	pink	pink	pink	pink	pink	pink
	Butt	Color	yellow	yellow	yellow	yellow	yellow	yellow
		Gas	+	—	—	—	+	+

Summarizing these tables it will be found that all three indicators may be used in media for the detection of acid. Phenol red is the most sensitive, as might be expected, then brom thymol blue and finally brom cresol purple. The last two proved very satisfactory and could almost be used interchangeably. The amount of acid produced is the determining factor in each case so that we might expect different results with different indicators. For example, typhoid and dysentery may be differentiated by their action on arabinose with brom thymol blue but not with brom cresol purple. Not enough acid has been produced to bring about a change with brom cresol purple. On the other hand, these same organisms may be differentiated by their action on mannose and galactose with brom cresol purple but not with brom thymol blue. In this case the action has gone too far to be detected with brom thymol blue.

All the sugars used were fermented by one or more organisms. Three of these, dulcitol, raffinose and sucrose were fermented with very little or no gas so that for this purpose they are of little or no use.

Arabinose will divide the group into four parts. Colon, typhoid and dysentery stand out by themselves while para A., para B., and enteritidus remain undifferentiated.

Dextrose is the most easily fermented of all the sugars used. Typhoid, dysentery and enteritidus stand out as distinct individuals while the other three show no difference in their reactions.

Galactose breaks up the group into five parts, para B. and enteritidus in one group and the other four as separate individuals.

Lactose is fermented only by colon.

Levulose gives different reactions for typhoid, dysentery, and para A. while the same reaction is given for colon, para B. and enteritidus.

Maltose is fermented by typhoid but not by dysentery, thereby distinguishing between these two. The others all give like reactions.

Like maltose, mannose will separate typhoid and dysentery but will further divide the remaining four into three groups, colon and enteritidus as separate individuals and the other two undifferentiated.

Rhamnose will distinguish between colon, para A., para B., and enteritidus. Typhoid and dysentery are undifferentiated.

Xylose gives one reaction for colon, para B. and enteritidus and another for typhoid, dysentery and para A.

SOIL BACTERIAL TYPES AND GREEN MANURING.

I. L. BALDWIN AND A. J. SMITH, Purdue University.

In an experiment to determine the effect of calcium carbonate on the biological activities of a soil, it was noted that the addition of green manure seemed materially to alter the equilibrium existing between the bacterial types. This point was deemed of sufficient importance to justify further study and as a result an effort was made to classify the bacterial types developing on agar plates from the treated and untreated soils.

Many investigators have reported the effect of various green manures on the number of bacteria developing in the soil and practically all have found a decided increase following the addition of green manure. However, few investigators have attempted to make a qualitative study of this increase. Hiltner and Stömer[1], in Germany, and Chester[2] and Conn[3], in this country, have carried out the most extensive work in studying and classifying the soil flora. Conn, whose work is far more thorough than any of the others, has classified the soil flora into three main divisions, spore formers, non-spore formers and Actinomycetes. In this same work, Conn reports that the addition of manure to soil disturbs the equilibrium between the bacterial types, greatly stimulating the non-spore forming group. Murray[4], in 1920, reports that the addition of straw to the soil does not appear to stimulate any one type môre than the others. Other investigators have reported similar results, the effect varying with the material applied to the soil.

The soil used in this experiment was a black sandy loam, containing a rather high percentage of organic matter and with a lime requirement of about 1,600 pounds calcium carbonate to the acre. Twenty gallon stone jars were filled with ten pounds each of the air dry soil and treated as follows:

Pots 1 and 6 received 500 pounds calcium carbonate per acre.
Pots 2 and 7 received 1,000 pounds calcium carbonate per acre.
Pots 3 and 8 received 2,000 pounds calcium carbonate per acre.
Pots 4 and 9 received 4,000 pounds calcium carbonate per acre.
Pots 5 and 10 received no calcium carbonate.
Pots 11 and 16 received 500 pounds calcium carbonate per acre.
Pots 12 and 17 received 1,000 pounds calcium carbonate per acre.
Pots 13 and 18 received 2,000 pounds calcium carbonate per acre.
Pots 14 and 19 received 4,000 pounds calcium carbonate per acre.
Pots 15 and 20 received no calcium carbonate.

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[1] Hiltner, L., and Stormer, K. Studien uber die Bakterienflora des Ackerbodens, mit besonderer Berucksichtigung ihres Verhaltens nach einer Behandlung mit Schwefelkohlenstoff und nach Brache. Kaiserl. Gesundheitsamte, Biol. Abt. Land- u. Forstw. 3, 445-545. 1903.

[2] Chester, F. D. Bacteriological analysis of soils. Del. Agr. Exp. Sta. Bul. 65. 1904.

[3] Conn, H. J. Soil Flora Studies. New York (Geneva) Agr. Exp. Sta., Tech. Bul. 57, 58, 59, 60. 1917.

[4] Murray, T. J. The effect of straw on the biological soil processes. Soil Science, 12, 233-259. 1921.

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In addition to the above treatment, each pot from 1 to 10 inclusive, received green manure in the form of young rye plants, at the rate of twelve tons per acre.

These pots were placed in the rose house of the Purdue horticultural greenhouses and planted to soybeans. Moisture and temperature conditions were kept at optimum.

Bacterial numbers were determined by plating with standard beef extract agar and incubating fourteen days at room temperature, which was about 20° C.

The bacterial types were studied by sub-culturing on each of the following media:

1. Beef extract agar slants.
2. Beef extract bouillon.
3. Beef extract gelatin stabs.
4. Nitrate reduction solution.
5. Dextrose fermentation tubes.
6. Lactose fermentation tubes.
7. Brom cresol purple milk.

Each culture was also studied miscroscopically, noting shape, spore formation and motility.

TABLE 1. Bacterial Numbers, Millions per Gram of Soil.

Treatment		Dates of Sampling			
$CaCO_3$ per acre	Green manure per acre	Oct. 19	Nov. 16	Dec. 14	Jan. 11
500 lbs	12 tons	1.2	20.0	4.2	7.0
1,000 lbs	12 tons	3.2	15.0	3.2	4.2
2,000 lbs	12 tons	3.5	10.5	5.7	4.5
4,000 lbs	12 tons	1.9	11.2	7.0	4.7
None	12 tons	0.8	9.2	3.9	4.7
Average		2.1	13.2	4.8	5.0
500 lbs	None	1.2	8.2	3.1	6.2
1,000 lbs	None	2.0	5.0	2.8	5.4
2,000 lbs	None	1.4	9.7	2.7	4.6
4,000 lbs	None	0.8	7.0	2.6	4.5
None	None	1.1	5.0	4.4	5.5
Average		1.3	7.0	3.1	5.2

Plate counts were made at four different times as shown in Table 1. While the applications of calcium carbonate exerted no appreciable effect on bacterial numbers, the application of green manure greatly increased the total count of bacteria. This is particularly true at the date of the second sampling, four weeks after the experiment was started, when decomposition of the green manure was progressing very

rapidly. At the date of the last sampling, three months after the experiment was started, practically all of the green manure had broken down and the bacterial counts were about the same as in those which had received no green manure.

At the date of the last sampling, ten colonies were picked from the agar plates of each treatment, making one hundred colonies, and were studied as previously described. Care was exercised to make as representative a selection as possible from each set of plates.

TABLE 2. Bacterial Types, as Influenced by $CaCO_3$ and Green Manure.

Treatment		Form			Motility		Sporulation		Gelatin liquefaction	
$CaCO_3$ per acre	Green Manure per acre	Coccus	Rod	Actinomycete	+	—	+	—	+	—
500 lbs.......	12 tons ..	2	6	2	5	5	6	4	9	1
1,000 lbs.......	12 tons ..	3	6	1	5	5	1	9	9	1
2,000 lbs.......	12 tons ..	3	7	0	2	8	2	8	10	0
4,000 lbs.......	12 tons ..	4	6	0	6	4	2	8	7	3
None...........	12 tons ..	3	6	1	3	7	5	5	8	2
Total	....	15	31	4	21	29	16	34	43	7
500 lbs.......	None....	3	4	3	2	8	5	5	7	3
1,000 lbs.......	None....	6	4	0	3	7	3	7	7	3
2,000 lbs.......	None....	3	5	2	5	5	5	5	9	1
4,000 lbs.......	None....	4	5	1	5	5	5	5	9	1
None..........	None...	7	3	0	3	7	2	8	7	3
Total......	....	23	21	6	18	32	20	30	39	11

Table 2 gives a summary of this work. As in the case of the total bacterial counts, it is seen that the calcium carbonate treatments have exerted no appreciable influence on the bacterial types. However the application of the green manure has caused considerable disturbance in the equilibrium existing between the various bacterial types. The rod forms have increased from 42 per cent of the total to 62 per cent, largely at the expense of the coccus forms. The spore formers have decreased from 40 per cent to 32 per cent, and the gelatin liquefiers have increased from 78 per cent to 86 per cent.

While these results cover only one small angle of a very large problem, they are indicative of what may be accomplished in the future. Each year it is becoming more apparent that our study of the soil flora must be directed toward a more thorough knowledge of the bacterial types and particularly the interrelationships existing between the various groups.

A SIMPLE METHOD OF DETERMINING THE THERMAL DEATH-POINT.

JAMES B. KENDRICK AND MAX W. GARDNER,

Purdue University Agricultural Experiment Station.

Methods of determining the thermal death-point of bacteria have been described by Novy[1], Sternberg[2], Smith[3], and many others. The apparatus ordinarily used is illustrated by Novy and by Smith. The standard procedure consists of a ten-minute exposure of a suspension of the bacteria in a capillary tube or test tube to the temperature desired by immersing the tube in a hot water bath. The methods vary as to the medium and the type of tube used for the suspension, the regulation of the temperature, and the mode of testing the viability of the organisms.

In recent studies of the thermal death-points of certain bacteria causing plant diseases, some modifications of the older methods have been adopted. A heavy suspension of each organism was made in a flask of sterilized distilled water, and equal amounts were then transferred with a sterilized pipette to small sterilized test tubes, one cm. in diameter and seven cm. in length, with walls of fairly uniform thickness. With plant pathogenes there seems to be no especial need of using bouillon or salt solution for these suspensions.

For the water bath a five-gallon wooden candy bucket was placed in a sink under a combination steam and cold water faucet from which a piece of hose led down into the bucket (fig. 1). By turning on either the cold water or the steam and stirring with a stick, the temperature of the water was easily adjusted and controlled. The temperature in such a container is more easily controlled than in the smaller metallic types because of the large volume of water and the relatively low thermal conductivity of the wood. If steam is not available, hot water can be used to raise the temperature since plant pathogenic bacteria are not spore-formers and have low thermal death-points. A. G. Johnson and others working at the University of Wisconsin have made use of a somewhat similar container.

The test tubes containing the organisms were inserted in holes bored in a large, flat, cork float about 15 cm. in diameter so as to project well down into the water. By means of a certified thermometer reading to one-tenth of a degree inserted through a cork into a similar test tube containing water and suspended at the center of the float, the exact temperature of the contents of the tubes could be controlled. The temperature of the water bath was adjusted before the cork float with the test tubes was placed on the surface. After the contents of the tubes had reached the temperature of the bath, a matter usually of about one minute, the float was allowed to remain ten minutes and then was

[1] Novy, Frederick G. Laboratory work in bacteriology. 1-563. 1899. p. 513.
[2] Sternberg, George M. A text-book of bacteriology. 1-708. 1901. p. 154.
[3] Smith, Erwin F. Bacteria in relation to plant diseases. *1*:1-285. 1905. p. 75.

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removed to a jar of cold water so as to cool the tubes at once. The tubes, properly labelled, were then removed to be tested and were replaced by another series of tubes to be exposed to the next higher temperature. Temperatures between 45° and 55°C. were thus tested. The viability of the organisms in each series of heated tubes was tested by means of loop transfers to tubes of slanted agar, and the suspensions

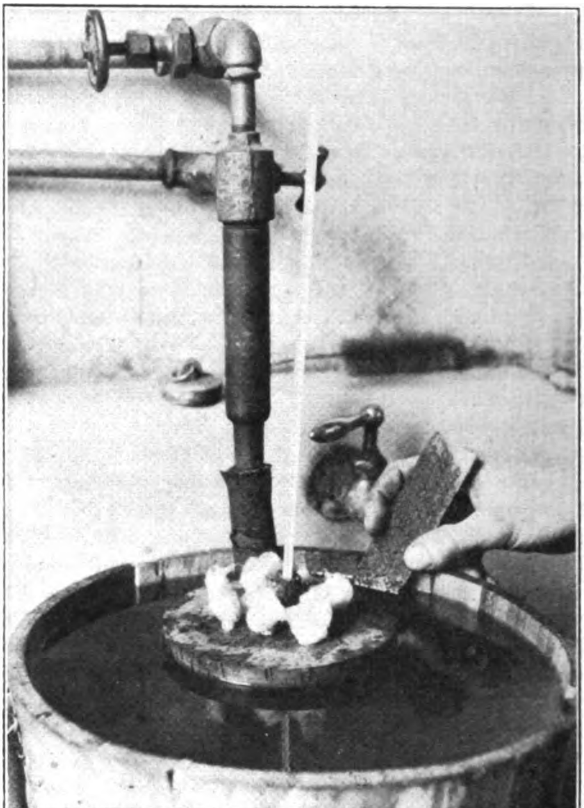

Fig. 1. Thermal death-point apparatus. Large cork float supports thermometer and a number of small test tubes containing the bacterial suspensions. Temperature of water bath adjusted by steam and cold water.

were preserved so that additional transfers might be made from those representing the critical temperatures.

To summarize, the essential phases of this method are the use of water suspensions in small test tubes, the use of a large, wooden container for the water bath in which the temperature is raised by the addition of steam or hot water, the use of a cork float to support the tubes and the thermometer, and the test for viability by making transfers to agar slants.

UNUSUAL STIPULES OF ACER NIGRUM MICHX.

FLORA ANDERSON, Indiana University.

In the autumn of 1921 when the leaves began to fall, some leaves of *Acer nigrum* were noticed that had very prominent stipules. The tree from which these leaves came is just north of Biology Hall on the Indiana University Campus. Since it is 45 to 50 feet to the first limb, no leaves were studied while on the tree. By examining the fallen leaves one could find almost all variations, from those having no noticeable stipules to those having very prominent aecidulated stipules on long slender stalks. The place of attachment of the stipules varied from the base of the petiole to the base of the blade (figs. 4 to 9). The blade of the stipule was either straight or aecidulated. Figures 3 and 4 show both types on the same leaf.

Britton[1] in his description of *Acer nigrum* says . . ; "the leaf-stalks are also hairy, at least when young, and are expanded at the base, often bearing stipules which are sometimes 3 or 4 cm. long". On a single tree one may find leaves with the petioles scarcely expanded at the base, and other leaves with very large, conspicuous stipules—the blade of the stipule sometimes 6 or 7 cm. long—on slender stalks (fig. 13). Then there may be found all gradations between these. Hough[2] says . . ; "petioles stout and generally bearing stipules at the enlarged base". He figures a branch and calls attention to "the presence of a few small stipules. They are occasionally much larger". Deam[3] in his description of the species says . . . "petioles usually 3-15 cm. long which are more or less swollen at the base and by maturity develop a scale-like appendage on each side of the petiole at the base—especially on each of the terminal pair of leaves, sometimes with foliar stipules which are 2-3 cm. long on stalks of equal length". His plate 114 is a photograph of a branch of *Acer nigrum* which shows two leaves with unusual stipules—one at the base of the petiole, the other near the blade of the leaf. Gray[4] mentions; "stipules often conspicuous" and again[5], "Stipules large, early deciduous." Quite a number of authors make no mention of stipules in their description of *Acer nigrum*.

Since the taxonomist had made no special note of these unusual stipules, the writer thought they might be "early deciduous", and in the spring of 1922 began to examine *Acer nigrum* trees for leaves with stipules of unusual character. During the spring and summer, trees on the Indiana University Campus and on the streets of Bloomington were observed. On almost all of these trees were found leaves of different types, varying from those with practically no stipules to those with large foliar aecidulated stipules on slender stalks. The point of attachment of

[1] Britton, Nathaniel Lord. North American Trees. p. 651. 1908.

[2] Hough, Romeyn Beck. Handbook of the Trees of the Northern United States and Canada. pp. 326-327. Fig. 382. 1907.

[3] Deam, Chas. C. Trees of Indiana. p. 246. pl. 114. 1921.

[4] Gray, Asa. New Manual of Botany. 7th Ed. p. 558. 1908.

[5] Gray, Asa. Field, Forest and Garden Botany. Revised. p. 112. 1895.

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Figs. 1-14. Types of stipules of *Acer nigrum Michx.* x ½.

these stalks to the petiole ranged from the base of the petiole to the base of the blade of the leaf. Observations made on trees in the state park at Spencer, Indiana, and on street trees in Crawfordsville and Ladoga, Indiana, revealed the same conditions. Neither the age nor the vigor of the tree seemed to make any difference in the relative number or kind of stipules produced.

When one sees a leaf with stipules like those in figures 1 and 2, there seems to be nothing unusual; but on observing one with stipules like those in figures 3, 5 and 11 where one sees apparently the normal stipule plus something else, there is a question. Are these structures a part of the so called "normal stipule", or are they structures originating in the axils of the stipules? Some leaves would seem to indicate that they were simply enlargements of the normal stipule (fig. 12). But other leaves show the slender stalks of the unusual stipules coming from the axils of the normal stipules. Even when these stalks come apparently from different places on the petiole, they can usually be traced by a ridge on the petiole back to the axil of the normal stipule (figs. 10 and 11). Sometimes three of these stipules may be found on one leaf (fig. 14), or one may fork as is shown in figures 10 and 13. Or, this stipule may be sessile at the base of the leaf blade, appearing at first glance as a lobe of the leaf (fig. 9). The blade of the stipule may be very simple and entire as is seen in figure 4, A; or it may be aecidulated and variously lobed as is shown in figure 6. The lobes of the stipule are frequently similar to those of the leaf blade.

By late summer, a few of these stipules had fallen, leaving only a slight scar. As far as the writer could ascertain, only a very few of these unusual stipules might be classified as "early deciduous". A great many of the leaves examined late in the autumn still retained their stipules. There seemed to be no tendency, except in a few instances for the stipules to be shed before the leaves fell.

In conclusion it might be said that all the trees examined had at least a few leaves with unusual stipules, but some trees showed a much larger proportion of stipulate leaves than others. Whether or not there is something inherent in the tree that causes it to produce these unusual stipules is not known. Observations of certain trees of opposite tendencies made from year to year, and seedlings from these trees might in a measure help to solve the problem. But before a definite conclusion can be formulated, it seems necessary to study a large number of trees of different localities, and also to study the origin of these unusual stipules morphologically.

DEVELOPMENT OF SPOROGENOUS TISSUE IN THE FOOT OF THE SPOROPHYTE OF PORELLA NAVICULARIS.

FLORA ANDERSON, Indiana University.

From fresh material of *Porella navicularis* sent from Corvallis, Oregon, in the fall of 1920, quite a number of young sporophytes were

fixed in one per cent chromo-acetic acid and later sectioned for class use. Whole buds were used for the sectioning, the sections being longitudinal and 15μ in thickness. Modified triple was used for staining the sections.

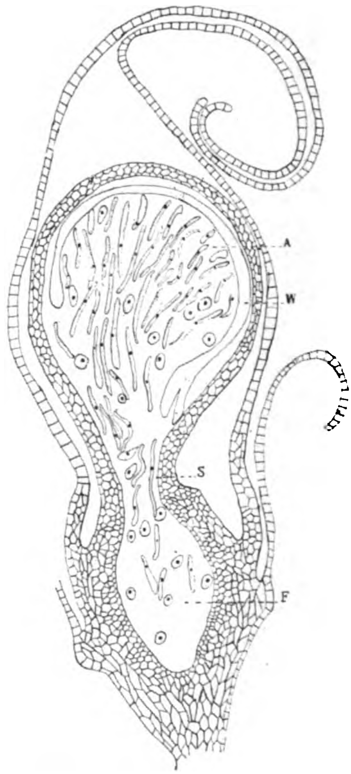

Fig. 1. Longitudinal section of bud of Porella showing unusual development of sporogenous tissue. x 45. A, sporangium; W, sporangium wall; S, stalk of sporophyte; F, foot of sporophyte.

On examining the slides, one was noticed which was different from the others. The gametophyte tissue surrounding the young sporophyte was apparently normal, but the sporogenous tissue had grown so vigorously that it occupied nearly the whole of the sporophyte. The cells of the foot, stalk and sporangium wall were shrunken and crowded out of place—the spores and elaters occupying most of the foot and stalk as well as the sporangium (fig. 1).

PLANTS NEW TO INDIANA, XI.

CHAS. C. DEAM, Bluffton, Indiana.

Duplicates of the species reported in this paper, excepting *Crotalaria sagittalis*, have been deposited in the Gray Herbarium or in the National Herbarium. The grasses were determined by Agnes Chase. The determination of the remaining species was either made or checked at the Gray Herbarium.

Isoetes engelmanni A. Br.

Norma E. Pfeiffer in her monograph of the Isoetaceae, published in the Annals of the Missouri Botanical Gardens, Vol. 9:206:1922, says that my number 22385 which was reported as *Isoetes braunii* belongs to this species. In the same publication she refers my number 20467, reported as *Isoetes foveolata*, to the same species.

Eragrostis hirsuta (Michx.) Nees.

Posey County, Aug. 20, 1922. No. 37704. In clayey soil along the roadside on the south side of Half Moon pond about nine miles southwest of Mt. Vernon.

Melica nitens Nuttall.

Clark County, May 7, 1922. No. 35456. Found growing in full sunlight on the narrow ledges at the top of a cliff along the Ohio River about a half mile east of the mouth of Fourteen-mile Creek. The cliff at this point faces to the south and is about 250 feet high.

Harrison County, May 11, 1922. No. 35548. In partial shade on the narrow ledges and in the talus of the cliff of the Ohio River about two miles southwest of Laconia.

Cyperus pseudovegetus Steud.

Posey County, August 19, 1922. No. 37685. Common in a roadside ditch three miles west of Hovey, or about seven miles southwest of Mt. Vernon.

Juncus dichotomus Ell.

Laporte County, June 26, 1922. No. 36704. In a prairie habitat along the railroad about one mile south of Wanatah. Rare here. This species was reported for Randolph County by Phinney but since no specimen exists, we have no means of checking the determination. A specimen is in the Gray Herbarium collected by Schneck which was determined to be this species. H. H. Bartlett and C. A. Weatherby have examined this specimen and both report it to be an immature specimen of *Juncus tenuis*. Smith reported Bartlett's examination in Proc. Ind. Acad. Sci. 1905:156:1906.

Carex annectans Bicknell.

Crawford County, May 28, 1919. No. 27710. In a low flat woods about three miles northwest of Leavenworth.

St. Joseph County, June 8, 1922. No. 36366. In an old marsh bed about five miles west of South Bend.

Silene chloranthe (Willd.) Ehrh.

Monroe County, Sept. 17, 1922. No. 37989. Collected by myself and Paul Weatherwax in sand ballast along the Monon Railroad about

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one and a half miles northwest of Harrodsburg. Corolla yellowish. Frequent here for a distance of about 25 feet.

Crotalaria sagittalis Linnaeus.

Perry County, Aug. 6, 1922. No. 36502. In an abandoned field near the crest of a ridge about two and a half miles east of Oriole. Associated with a thick stand of *Cassia chamaecrista*. First discovered by Mrs. Chas. C. Deam. After a search over an acre or more we found only two specimens. This species was reported by Schneck as occurring in the lower Wabash Valley but he cited no definite locality. Indiana is included in the range of this species in the Gray Manual, but the Gray Herbarium does not contain a specimen from Indiana.

Ludwigia glandulosa Walt.

Posey County, Aug. 20, 1922. No. 37699. In an open swamp in a woods in the southwest corner of Section 32 of Point Township. Closely associated with *Cephalanthus occidentalis*, *Styrax americana*, *Lobelia cardinalis*, *Ludwigia polycarpa* and other plants about four feet high.

Chaerophyllum procumbens, variety *shortii* T. & G..

Clark County, May 7, 1922. No. 35477. Alluvial bank of the Ohio River about three-fourths of a mile above the mouth of Fourteen-mile Creek. *C. procumbens* was found about one-fourth mile from the variety and was just beginning to mature its fruit while at the same time the variety was in full fruit, apparently about ten days difference.

Lappula redowskii, variety *occidentalis* (Wats.) Rydb.

Porter County, June 25, 1922. No. 36680. Frequent along the right of way of the Pere Marquette Railroad about five miles southwest of Michigan City.

Mentha cardiaca Gerarde.

Spencer County, Aug. 9, 1922. Several specimens were found in a pasture field about two miles north of Lamar. It grew in a hard clay soil in a low flat field.

Plantago purshii R. & S.

Newton County, June 11, 1922. No. 36502. On a cleared black oak ridge just west of Conrad. Growing in almost pure sand with *Koeleria cristata*, *Stipa spartea*, *Carex brevior*, *Lithospermum gmelini*, *Panicum pseudopubescens*, *Panicum scribnerianum* and *Panicum perlongum*. This is the first definite record for Indiana, although both Gray's Manual and Britton and Brown's Ill. Flora ed. 2, credit Indiana with it. There is no specimen of this species from Indiana in the Gray Herbarium or the New York Botanical Gardens.

Houstonia angustifolia Michx.

Harrison County, Aug. 3, 1922. No. 37238. Growing in very shallow soil in an exposed place on the top of the limestone bluff of the Ohio River about one and a half miles northeast of Davidson.

Sonchus uliginosus Bieb.

Noble County, July 11, 1922. No. 36832. A colony in dry soil in blue grass sod on the west side of the road three and a half miles south of Albion.

THE EFFECT OF PRESSURE ON GROWTH.

F. M. ANDREWS, Indiana University.

Numerous experiments have been carried out to show the effect of air pressure on plants. Among these may be mentioned the work of Bert[1]. Later Wieler[2] studied the question of reduced pressure of oxygen and Jentz[3] of increased oxygen pressure. Some of these facts are also set forth by Pfeffer[4]. Czapek[5] also points out a number of interesting researches on this subject.

The points to be mentioned briefly here, however, refer to the effect of water pressure on plant growth. That the roots of plants grow when submerged in water is common knowledge but when the pressure of the water is increased there is an effect which varies with the intensity of the pressure. The writer noticed long ago that centrifuging caused the roots of corn seedlings to become translucent due to the fact that part of the water surrounding the seedlings was forced into the roots. For example, the roots of the control or uncentrifuged seedlings retained their normal color in water, but those which were centrifuged and subjected to a force equivalent to a column of water 30 meters high, became clear in 15 minutes.

The combined action of centrifugal force and water pressure was observed in another experiment. In this case control seedlings of corn which were 3 cm. long grew 2 mm. in water in four hours at 24°C. The centrifuged corn seedlings of the same size and under exactly the same conditions grew only 1 mm. in four hours, under a water pressure of 30 meters. Numerous other experiments performed in this way using both smaller and greater amounts of water pressure verified these results.

In another series of experiments the seedlings of corn were subjected to water pressure without the action of centrifugal force. Corn seedlings 3 cm. long and used as controls grew, on the average, 2.1 mm. in four hours at 24°C. in this set of experiments. The corn seedlings 3 cm. long and which were subjected to a pressure of 30 meters of water grew 1.5 mm. in four hours at 24°C. The effect of pressure in this case which was equal to a column of water 30 meters in height amounted, therefore, to a growth check of .6 mm. in four hours.

A third series of experiments was performed to test out the effect of extremely high pressures on the growth of seedlings. Corn seedlings 2 cm. long were exposed to water pressure of 50 atmospheres at a favorable temperature for five minutes. At the end of this time the roots so treated were clear. These seedlings and other corn seedlings 2 cm. long used as controls were planted in sawdust. In 24 hours the

[1] Bert, P. Compt. rend. 1877 Tome 84 p. 1130.

[2] Wieler, A. Die Beeinflussung des Wachsens durch verminderte Partiärpressung des Sauerstoffs. Unters. a. d. Bot. Institut z. Tübingen 1833 Bd. I. p. 189.

[3] Jentys, Stefan. Ueber den Einfluss hoher Sauerstoffpressung auf das Wachstum der Pflanzen. Unter a. d. Bot. Institut z. Tübingen 1886 Bd. II p. 419.

[4] Pfeffer, W. Pflanzenphysiologie Zweite Auf. Bd. I. p. 548; Bd. II p. 133-134.

[5] Czapek, F. Biochemie der Pflanzen 1905 Bd. II, p. 396 and the literature quoted in the above references.

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controls were 4 cm. long while the seedlings from the pressure test were 3.6 cm. long. They continued to show some difference for three days after which time all were of the same average size and vigor.

Corn seedlings 2 cm. long were subjected in the second experiment to 100 atmospheres pressure under the same conditions. After 24 hours the controls averaged 4 cm. in length while the experimental seedlings were 3.2 cm. long on the average. In five days all were equal in size and vigor. Other experiments showed these seedlings to have become clear in three minutes.

In a third experiment corn seedlings 2 cm. long were placed in a water pressure of 200 atmospheres for five minutes. They became clear in about two minutes. When planted the controls averaged 4.2 cm. while the experimental seedlings averaged 2.8 cm. In seven days all seedlings averaged the same size and were equal in vigor.

In a fourth series of experiments corn seedlings 2 cm. long were placed in a water pressure of 400 atmospheres for five minutes. Experiments showed that they became clear on the average in one-fourth of a minute. In 24 hours the controls averaged 4.1 cm. in length while the test plants were 2.5 cm. long. In 12 days all seedlings were equally large and vigorous.

Finally corn seedlings 2 cm. long were placed in a water pressure of 600 atmospheres. As nearly as could be determined they became clear on the average in 10 seconds. In 24 hours the controls averaged 4.3 cm. and the test plants averaged 2.3 cm. in length. In 18 days all seedlings were of equal size and vigor. The high pressure recorded in the last five experiments was obtained by means of a Geneva Society high pressure pump which will produce pressures up to 1000 atmospheres. Melsens[6] states that yeast will live under a pressure of 8000 atmospheres. Corn seedlings can withstand great pressure and recover in a comparatively short time. It is to be noticed, however, that the time of recovery is delayed according to the intensity of the pressure.

[6] Melsens. Comp. rend. 1870. Bd. 70 p. 831.

CHLOROPLASTS OF *MARTYNIA FRAGANS*.

F. M. ANDREWS, Indiana University.

Martynia shows an interesting arrangement of the chloroplasts in the trichomes on the stems and elsewhere. This arrangement together with the rate of movement of the chloroplasts form the chief points of this paper, which for the plant above mentioned, have not heretofore been determined. Senn[1] has studied a large number of other plants as regards their chloroplasts. Stahl[2] also has investigated the subject and Noll[3] has studied the movements of the chloroplasts in *Schistostega osmundacea.*

The trichomes of Martynia vary in length, some being more than two mm. long. Those under consideration terminate in an enlarged end. Viewed collectively they impart to the plant a velvety appearance, and the rather large clear drop of viscous liquid, often seen on their

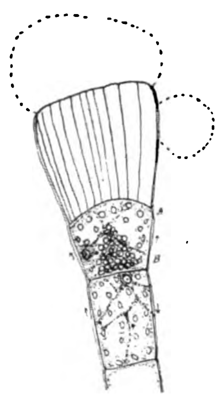

Fig. 1. Top of trichome of Martynia.

ends, gives to the plant its clamminess (fig. 1). When magnified only five times and observed laterally the transverse walls of many of the larger trichomes can barely be seen since they consist of a single roll of cells. When magnified five times, the presence of the chlorophyll color may be discerned in the region occupied by the two cells just under the end of the trichome. The microscope shows few chlorophyll granules near the base of the trichome. This is easily observable since the cell walls are thin. The interior of the cell is clear except for the chloroplasts. Protoplasmic movements are visible in various directions as indicated by the arrows in figure 1. The trichomes near the tip of the plant where the light is more favorable possess more chloroplasts.

The chief interest centers in the first terminal chlorophyll-bearing cell (fig. 1). Under one set of light conditions the chloroplasts collect

[1] Senn, Gustav. Die Gestalts und Lageveränderung des Pflanzen-Chromatophoren 1908 and literature there quoted.

[2] Stahl, E. Botanische Zeitung 1880 Bd. 83. pp. 297, 321, 345, 361, 377, 393, 409.

[3] Noll, F. Arbeiten des Botanischen Instituts in Würzburg Bd. 3 pp. 477-488.

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at the end of the cell marked B, and under other conditions collect at A. The speed, however, with which these and other movements of the chloroplasts takes place is unusual. Senn[4] has shown that the chloroplasts of Funaria under optimal conditions of light move 4μ in eight minutes. The chloroplasts of the trichomes of Martynia, however, under optimal conditions of light move much faster, in fact, namely, 21μ in seven minutes. In the cells observed it required from 37 to 43 minutes under fairly constant optimal light and temperature conditions for the chloroplasts to traverse the cell. This shifting of the chloroplasts leads to the well known change in chlorophyll color of certain plant organs.

QUANTITATIVE ESTIMATION OF AERATION IN LEAVES.

F. M. ANDREWS, Indiana University.

It has been known for a long time that air can be made to move back and forth through the stomata of leaves and that this can be accomplished in some plants with only a slight force[1]. Some plants allow the passage of air in this way with marked ease and among them may be mentioned the following: Nymphaea, Funkia, *Calla aethiopica*, *Arum maculatum*, and Rumex[2]. To these I might add *Myriophyllum proserpinacoides* which is cultivated in aquaria.

A quantitative estimation of the amount of air which can be passed through leaves has not been made. The first investigator to see air pass in this way from stomata was Raffeneau Delille[3]. Since that time Sachs[4] and others have worked on the problem.

I have experimented with a number of plants in this respect. One of these was *Nymphaea odorata* which was an especially favorable object. Air was easily caused to pass through the leaf in bubbles with a vacuum of 12 mm. of mercury, which is less force than was required by the specimens of the same genus mentioned by Pfeffer[5]. The same thing was accomplished by arranging the petiole under a cylinder of water filled to a height of about 30 cm. and then inverted over a dish of water as indicated by Jost[6]. The air in this case issued from the petiole with great rapidity and in large quantity. The stream of bubbles can easily be made visible to a large audience by proper arrangement of a lens of correct magnifying power. The volume of air thus passed through the leaf of *Nymphaea odorata* was 10 cc. in 16 seconds. One thing must be borne in mind with *N. odorata* and that is the status of the leaf for

[4] Senn. l. c. p. 320.

[1] Pfeffer, W. Pflanzenphysiologie Zweite Auf. 1894 Bd. 1 pp. 178-179 and literature there quoted.

[2] Pfeffer, W. l. c. p. 179.

[3] Raffeneau, Delille. Annales d. Scien. natur. 1841. XIV 328. Quoted by Von Hohnel Jahr. f. wiss. Bot. 1879. Bd. 12 p. 48. See other literature there quoted.

[4] Sachs, J. Ueber die Bewegung der Gase in den Pflanzen. Handbuch der Experimental-Physiologie des Pflanze 1865 pp. 243-262.

[5] Pfeffer, W. l. c.

[6] Jost, L. Lehrbuch der Botanik. 15 Auf. 1921 p. 216.

an air passage. If the petiole of such a leaf is arranged as above indicated the air may not issue from the cut end of the petiole for a very long time, or not at all under slight vacuum. At times as much as 30 minutes elapse under slight vacuum before the air passage begins. When, however, it has once begun it continues with great rapidity until the expelling force is removed. When the passage of air does not begin at once the suction should be increased by lengthening the mercury or water column till the flow of bubbles commences. The force employed may then be decreased if desired to the minimum amount that will sustain a continuous stream of air bubbles. The stream of air bubbles will cease as soon as the leaf is immersed and will commence again as soon as it is restored to the air. This proves that the failure of air to pass at first under slight vacuum was not caused by the stomata being blocked with water, but was due to other causes. Large quantities of air issued even under the small vacuum. The leaves tested were of medium size, being about 12 cm. wide and 14 cm. long, and were vigorous in every respect.

Myriophyllum proserpinacoides allows air to pass with ease but not quite so easily as *Nymphaea odorata.* For example, a vacuum of 16 mm. of mercury was required to cause the air to flow through this plant from the leaves. The volume of air passed through was much less than for *N. odorata.* For example, it required five minutes for 1 cc. of air to emerge from the stem. The combined amount of surface of many leaves of *M. proserpinacoides* is much smaller than a single one of *N. odorata* so that the difference per unit area is not so great as might be expected.

The genus Rumex offers a very interesting land type of this function in contradistinction to the two foregoing aquatic types. The species experimented with was *R. obtusifolius.* Leaves 10 cm. wide and 16 cm. long were used. In these leaves a vacuum of only 28 mm. of mercury was required to cause the air to flow through the stomata and out of the petiole. Quantitatively the amount of air passed through the leaf was much less than in either of the first two plants discussed. At a minimum vacuum of 28 mm. of mercury only 1 cc. of air passed through the petiole in 17 minutes. As in the case of the first two plants, this flow instantly ceased when the leaf was submerged in water but began again when restored to the air. This, however, did not occur quite as quickly in the case of *R. obtusifolius.* The stomata of the leaves of *R. obtusifolius* are large. If one knows the size of the stomata and the volume of the air which issues, the number of stomata per unit area may therefore be easily calculated. If the leaves of these plants are attached directly through rubber stoppers or in tubes the amount of vacuum necessary to bring about the desired result is so small that the union may easily be made air tight by the use of plastilina. While in most plants the interchange of air is effected with much greater difficulty, the quantitative estimations here given for the three plants above mentioned show clearly the decided capabilities of certain plants in this respect. *Rumex obtusifolius* and *Myriophyllum proserpinacoides* can be used as excellent demonstration material before an audience. When *R. obtusifolius* was connected with a 1200 cc. flask on which a vacuum of 20 cm. of mercury

was placed the air was caused to stream inwardly through the stomata and out of the petiole continuously for two and one-half hours without renewing the vacuum.

AN UNUSUAL IRIS.

F. M. ANDREWS, Indiana University.

Two years ago I transplanted the rhizomes of some Irises to a rather damp location. All were the common large blue flag (*Iris versicolor*). The rhizomes sent up the aerial parts and produced 60 flowers of which three were unusually large, being 12 cm. long and nearly as broad, whereas the usual length is 5 to 8 cm. This represents an increase in size of at least one third. The inner segments were pure yellow and only about one-half the length and breadth of the sepals. Ordinarily the flowers of this species are colored yellow, green or white toward the center[1]. The petals were marked in places by purple dots which recalled to a degree the appearance of the flower of *Belamcanda chinensis*. The rhizomes from which these three flowers above mentioned came bore in every other instance blue flowers of the normal size and color.

SECOND BLOOMING OF SNOWBALL BUSH IN THE SAME YEAR.

F. M. ANDREWS, Indiana University.

On September 4, 1922, the writer noticed an account of a snowball bush which was in bloom for the second time that year. The plant was at the home of H. P. Carpenter of Elwood, Indiana, who, upon request, very kindly forwarded to me a cluster of the flowers and a branch with some leaves so that a study of the specimen could be made. He wrote that "the first time it was in bloom the bush was literally covered with blossoms, but the last time there were only a few, probably a dozen or more". This agrees with some other plants which have bloomed more than once in a season and to which the author has previously made reference[1]. The second blooming was conspicuous in specimens that were more or less diseased, due apparently to the attack of fungi or other injury. Injury may easily be caused by the attacks also of insects of various kinds and the snowball is at times injured to a high degree by this means.

The characteristics of the specimens at hand agree with *Viburnum opulus* or what is sometimes called the guelder rose or snowball. The flowers are white and are borne in a long peduncled cyme about 6 cm. in diameter. This however, falls far short of the usual size of the normal cyme clusters of *V. opulus* which often average 12 cm. in diameter.

[1] Gray, Asa. New Manual of Botany Seventh Edition.

[1] Andrews, F. M. Proceedings of the Indiana Academy of Science 1905, pp. 187-188; 1909, pp. 373-374; 1911, pp. 279-281.

Therefore, it is to be observed, that, during the second anthesis the number of clusters was greatly reduced, and the size of the individual cymes was much less.

Ordinarily *V. opulus* blooms in the early summer so that in this case about two months or more must have elapsed between the first and the second anthesis. Certain other species of this genus may be "forced" to bloom by the addition of heat during cold weather.

Regarding the second blooming of plants in the same season we have various suggestions as to its cause. If branches of certain plants are allowed to project into a warm greenhouse during the winter, these branches will develop transpiring leaves although the remainder of the plant may be outside in low temperature. This shows that water is still absorbed by the roots and passed through the stem.[2] Some plants under such conditions are unable to absorb water from a frozen soil and hence wilt.[2] Kerner[3] observed that a root of a Clematis plant growing in cold air and frozen developed leafy stems when a branch was conducted into a hothouse. The food substances made in the summer were available for use as soon as deposited[2]. He says further: "The same must indeed be the case in those plants which bloom normally in the spring, but yet often in years characterized by particularly mild autumns, burst open in October, the buds destined for the next spring thus sending out fresh leafy shoots and blossoms twice in the same year—for example,—many apple and horse chestnuts, violets and strawberries, many primulas, gentians and anemones." So in the case of the second blooming of the snowball here discussed, a rather high temperature might have influenced the plant to renew fruiting activity. Reference to the local weather bureau records shows that the temperature ran high during the second blooming of this plant. This influence of temperature on the second blooming of plants is upheld by an account by Darwin and Shrubbs entitled "Records of Autumnal or Second Flowerings of Plants". They enumerate 75 such plants in England and further state: "It can hardly be doubted that these second flowerings are connected with relatively high temperatures"[4].

Recently an account of an eight to nine year old cherry tree near Bloomington, in full bloom for the second time in the same season, came to the notice of the writer. Here again the high temperature prevailing during the second blooming of this tree indicates strongly the close connection between high temperature and the second seasonal blooming of plants.

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[2] Pfeffer, W. Physiology of Plants. English Edition Vol. 1, p. 231.

[3] Kerner, H. and Oliver, T. W. English Edition. Vol. 1, p. 564.

[4] Darwin, Frances and Shrubbs, A. Records of Autumnal or Second Flowerings of Plants. The New Phytologist 1922. Vol. 21, p. 48.

THE CONVOLVULACEAE OF INDIANA.

TRUMAN G. YUNCKER, DePauw University.

The family Convolvulaceae is represented in Indiana by the genera Quamoclit, Ipomoea, Convolvulus and Cuscuta. The eight species of Cuscuta known to occur in our State have been discussed by the writer in recent papers[1] presented to this Academy. It is proposed, in the present paper, to present the species of the other three genera occurring in Indiana and indicate their distribution and prevalence. Eleven species may be recognized, one in the genus Quamoclit, four in the genus Ipomoea, and six in the genus Convolvulus. All of these eleven species present fairly definite and constant characters by which they may be identified, with the possible exception of *Convolvulus sepium* and its close relative *C. fraterniflorus*. A study of a larger number of collections of these two species gathered over a wider range may show the inadvisability of maintaining them as separate species. Most of the species show considerable variation in the shape of the leaves. In *Ipomoea lacunosa*, for example, one may discover leaves of two or three distinctly different shapes even on the same plant. Sketches are presented showing this variation in leaf form and size in the different species.

All of the specimens that could be obtained were studied and compared. Mr. C. C. Deam's extensive collection was generously placed at the writer's disposal and provided the largest number of specimens. All collections are listed and the county in which they were obtained is indicated. No collections or localities are included where the specimens were not seen by the writer.

KEY.

Corolla tubular, not expanded at the base, limb salverform; stamens and style exserted; flowers not subtended by bracts .... 1. *Quamoclit coccinea*.

Corolla mostly funnelform, stamens and styles not exserted

  Stigmas 2 or 3, grouped into a rounded, frequently papillate, knob; flowers not subtended by bracts .... (Genus Ipomoea).

   Stems, petioles and peduncles retrorsely hairy

    Sepals mostly long, attenuate-caudate, tips spreading...... 2. *Ipomoea hederacea*.

    Sepals ovate-oblong to lanceolate. 3. *Ipomoea purpurea*.

[1] Notes on our Indiana dodders. Proc. Ind. Acad. Sci. for 1919. pp. 157-163.
A Species of Cuscuta not hitherto reported from Indiana. Proc. Ind. Acad. Sci. for 1920. p. 229.

"Proc. 38th Meeting, 1922 (1923)."

Stems, etc., not retrorsely hairy
Sepals broadly ovate or oblong, smooth .... 4. *Ipomoea pandurata.*
Sepals ovate to lance-ovate or oblong, pointed, hairy....... 5. *Ipomoea lacunosa.*
Stigmas 2, oval or filiform, elongated; 2 bracts closely subtending each flower (they are some little distance from the flower in *C. arvensis*) .... (Genus Convolvulus).
Petioles mostly less than one-fourth as long as the blade; plant short, upright, hairy.......... 6. *Convolvulus spithamaeus.*
Petioles mostly more than one-fourth as long as the blade; plant trailing or twining
Flowers double .... 7. *Convolvulus japonicus.*
Flowers single
Bracts surrounding and enclosing the calyx
Leaves smooth or, infrequently, hairy; peduncles mostly longer than the petioles. 8. *Convolvulus sepium.*
Leaves hairy
Leaves moderately hairy, hastate, peduncles not exceeding the petioles ..... 9. *Convolvulus fraterniflorus.*
Leaves densely hairy, basal lobes rounded, peduncles exceeding the petioles ...10. *Convolvulus repens.*
Bracts small and at some distance from the flower......11. *Convolvulus arvensis.*

1. QUAMOCLIT COCCINEA.

Figs. 1 & 2.

Quamoclit coccinea Moench, Meth. 453. 1794.

Plant smooth or slightly hairy at the nodes; leaves cordate, entire, or, infrequently, angled; peduncles one- to several-flowered and longer than the petioles; sepals bearing a prominent, dorsal projection; stamens and styles exserted.

Along roadsides and in cultivated fields.

Specimens examined:—Gibson Co. (Deam *18,306*); Harrison Co. (Deam *18,735*); Jefferson Co. (Coulter in 1874); Lawrence Co. (Deam *18,443*); Putnam Co. (Yuncker *1,353*); Sullivan Co. (Deam *32,922*); Warrick Co. (Mrs. Deam *33,117*).

2. IPOMOEA HEDERACEA.

Figs. 3 & 4.

Ipomoea hederacea Jacq. Icon. Rar. pl. 36. 1781.

Plants hairy, with the hairs on the stems, petioles and peduncles pointing downward; leaves three-lobed; sepals long, attenuate-caudate, tips curving, densely hairy at the expanded base.

Rather common in cultivated fields and waste places.

Specimens examined:—Clark Co. (Deam *5,433*); Crawford Co. (Deam in 1899); Franklin Co. (Deam in 1903); Greene Co. (Deam *37,711*); Hancock Co. (Deam *37,841*); Jefferson Co. (Coulter in 1875); Marion Co. (Deam *7,350*); Morgan Co. (Deam *2,692*); Perry Co. (Deam *37,419*); Posey Co. (Deam *37,698*); Putnam Co. (McDougall in 1888 and in 1889; Yuncker *1,355*); Vigo Co. (Deam *32,900*).

3. IPOMOEA PURPUREA.

Figs 5 & 6.

Ipomoea purpurea (L.) Lam. Tabl. Encycl. 1:466. 1791.

Plants hairy, with the hairs on the stems, petioles and peduncles turned downward; leaves cordate, or, infrequently, angled; sepals ovate or oblong, acute, densely hairy at the base.

In cultivated fields, along roadsides and in waste places generally.

Specimens examined:—Putnam Co. (Bates in 1911; Grimes 778; Yuncker *1,354*); Shelby Co. (Deam *19,082*); Spencer Co. (Deam *37,492*).

Specimens collected in Kosciusko and Wells Counties by Deam (Deam *1,498* and *5,296*), have sepals similar to those of *I. purpurea*, but the leaves are lobed and in all respects are similar to those of *I. hederacea*, while a specimen collected in Putnam County showed the contrary condition, i.e., it had the calyx lobes of *I. hederacea* and the leaves of *I. purpurea*. These combinations of characters suggest a cross between these two closely related species. So far as I have been able to find, no mention has been made before of this combination of characters.

4. IPOMOEA PANDURATA.

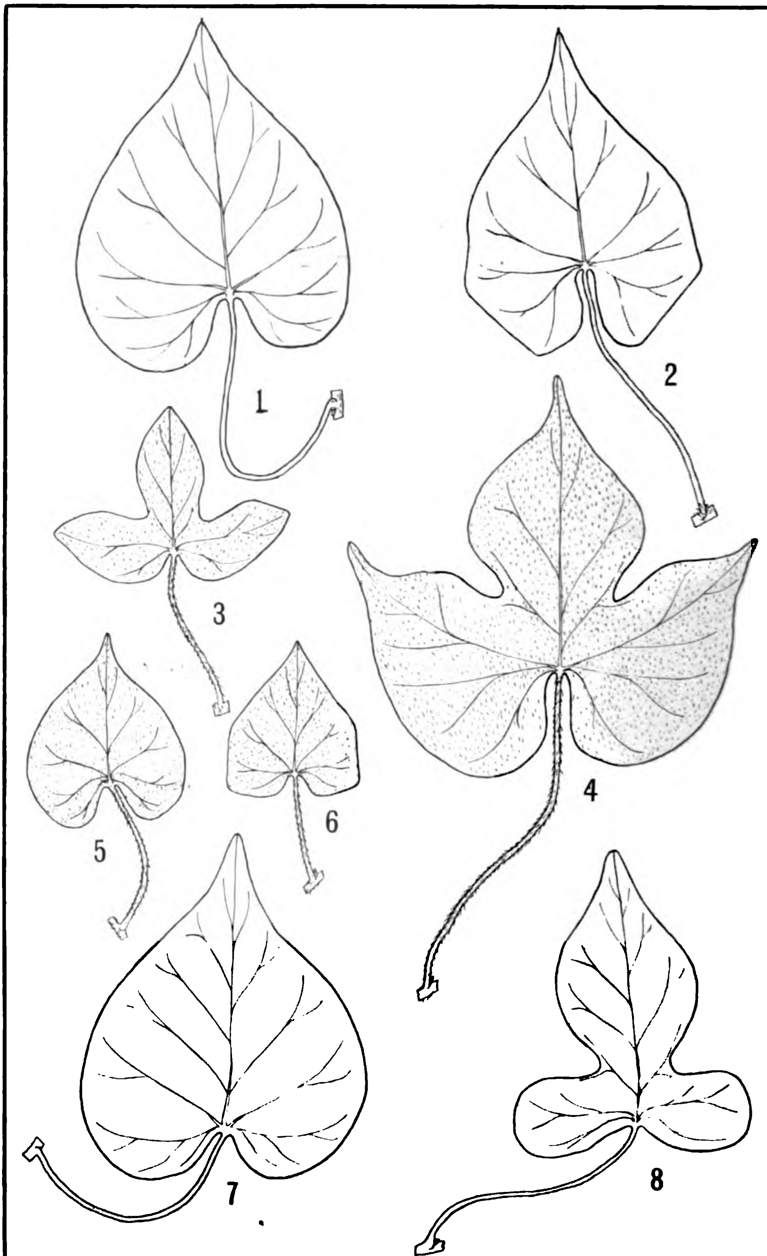
Figs. 7 & 8.

Ipomoea pandurata (L.) G.F.W.Mey. Prim.Fl.Esseq. 100. 1818.

Plant robust, smooth or, rarely, hairy; leaves ovate or, infrequently, constricted at the middle forming basal lobes; peduncles mostly longer than the petioles, 1-6 flowered.

Common in dry soil in waste places.

Specimens examined:—Allen Co. (Deam *1,358*); Blackford Co. (Deam *1,181*); Clark Co. (Deam *7,039*); Daviess Co. (Deam *25,643*); Dubois Co. (Deam *11,589*); Hamilton Co. (Mrs. Deam *12,151*); Harrison Co. (Deam *37,212*); Jefferson Co. (Coulter in 1875); Jennings Co. (Deam *37,021*); Knox Co. (Deam *17,006; 37,721*); Perry Co. (Deam *37,392A; 37,418*); Posey Co. (Deam *37,711*); Putnam Co. (Grimes *673;*



Figs. 1-8. Leaves of Convolvulaceae. 1 and 2, *Quamoclit coccinea;* 3 and 4, *Ipomoea hederacea;* 5 and 6, *I. purpurea;* 7 and 8, *I. pandurata.*

Yuncker in 1920); Shelby Co. (Mrs. Deam *11,580*); Spencer Co. (Deam *37,487*); Tippecanoe Co. (Dorner in 1900); Warrick Co. (Deam *37,661*); Wells Co. (Deam in 1897 and in 1903).

5. Ipomoea lacunosa.

Figs. 9-12.

Ipomoea lacunosa L., Sp. Pl. 161. 1753.

Plants smooth or hairy; leaves entire, or, more commonly, lobed or angled; flowers white or sometimes pink, red or purplish; sepals pointed and bristly hairy, chiefly along the margin; peduncles mostly shorter than the petioles, one to several flowered.

Common in cultivated fields, along river banks and low ground.

Specimens examined:—Clark Co. (Deam *5,432; 7,157; 12,095*); Clay Co. (Deam *37,781*); Floyd Co. (Deam *14,009*); Gibson Co. (Deam *9,934*); Greene Co. (Deam *37,751; 37,947*); Jackson Co. (Deam *38,063*); Jefferson Co. (Coulter in 1876; Deam *18,849*); Knox Co. (Deam *32,934*); Owen Co. (Mrs. Deam *10,204* in part with *Convolvulus sepium*); Perry Co. (Deam *33,223; 33,224; 37,344*); Posey Co. (Deam *22,337*); Putnam Co. (Grimes *251;* Yuncker in 1920); Spencer Co. (Deam *37,491*); Sullivan Co. (Deam *18,263*); Warrick Co. (Deam *37,660*); Washington Co. (Deam *18,978*).

6. Convolvulus spithamaeus.

Figs. 31-16.

Convolvulus spithamaeus L., Sp. Pl. 158. 1753.

Plants pubescent, usually not more than one foot high, erect, infrequently showing a tendency to twine; petioles mostly not more than one-fourth the length of the blade, in rare specimens slightly longer; peduncles exceeding the petioles; bracts mostly oval or, rarely cordate.

In dry soil on hillsides, river banks, etc.

Specimens examined:—Clarke Co. (Deam *6,481; 6,581*); Harrison Co. (Deam *23,399*); Noble Co. (Deam *6,776*); Porter Co. (Deam *20,060*); Steuben Co. (Deam in 1904); Tippecanoe Co. (Deam in 1901); Wells Co. (Deam in 1899); Whitley Co. (Deam *23,707*).

7. Convolvulus japonicus.

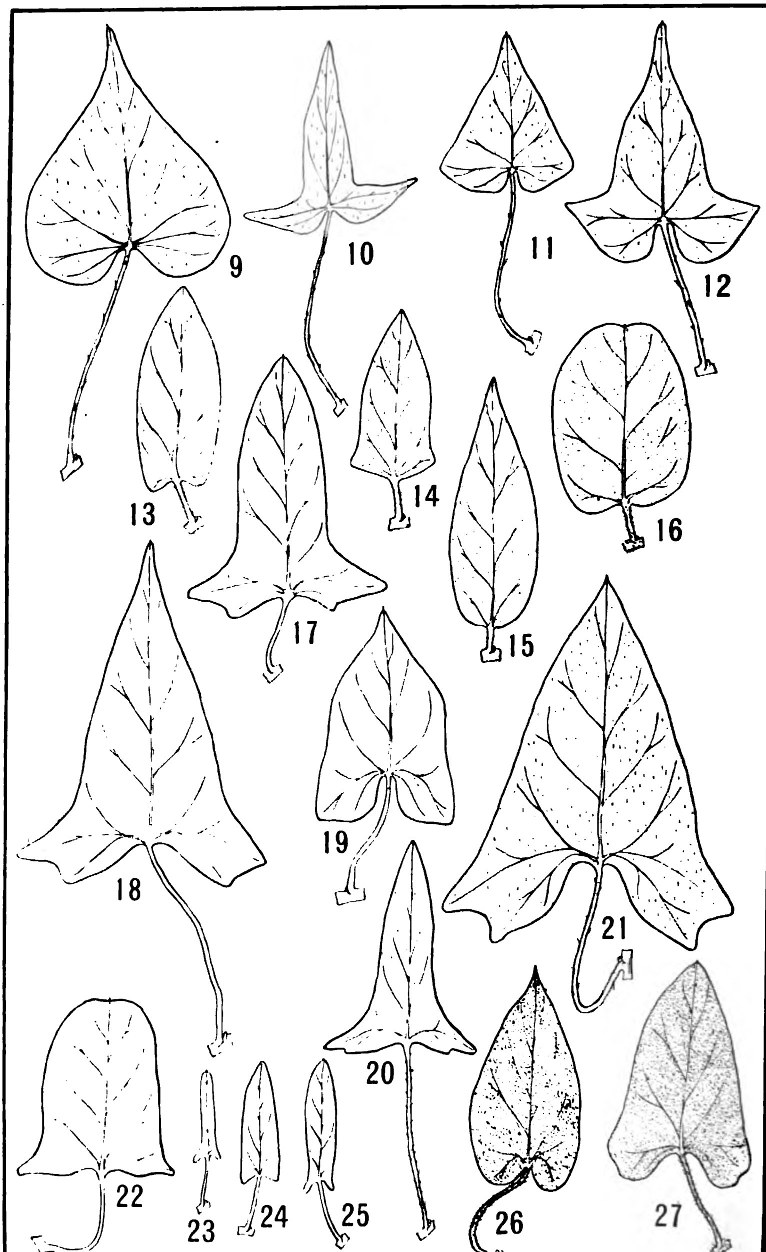
Fig. 17.

Convolvulus japonicus Thunb., Fl. Jap. 85. 1784.

Plants hairy; petioles much shorter than the blade; peduncles longer than the petioles; flowers double.

In moist, waste places. Rare.

Specimens examined:—Putnam Co. (Yuncker *1,352*); Tipton Co. (Grimes *942*).



Figs. 9-27. Leaves of Convolvulaceae. 9-12, *Ipomoea lacunosa;* 13-16, *Convolvulus spithamaeus;* 17, *C. japonicus;* 18 and 19, *C. sepium;* 20 and 21, *C. fraterniflorus;* 22-25, *C. arvensis;* 26 and 27, *C. repens.*

8. Convolvulus sepium.

Figs. 18 & 19.

Convolvulus sepium L., Sp. 153. 1753.

Plant smooth or slightly hairy; peduncles equal to or longer than the petioles and only one in each axil.

Common throughout the State in moist situations.

Specimens examined:—Allen Co. (Deam *1,359*); Brown Co. (Deam *11,200*); Floyd Co. (Deam *37,203*); Hamilton Co. (Mrs. Deam *8,711*); Hendricks Co. (Mrs. Deam *11,230*); LaPorte Co. (Deam *36,706*); Noble Co. (Deam *14,323*); Owen Co. (Mrs. Deam *8,966;* Mrs. Deam *10,204* in part with *Ipomoea lacunosa*); Perry Co. (Deam *37,388A*); Putnam Co. (Grimes *646;* McDougall in 1888; Yuncker *1,294*); Ripley Co. (Deam *13,801*); Shelby Co. (Mrs. Deam *11,365*); Steuben Co. (Deam *1,255*); Tipton Co. (Mrs. Deam *14,105*); Vermillion Co. (Deam *37,926*); Warrick Co. (Deam *37,593*); Wells Co. (Deam in 1901 and in 1903).

9. Convolvulus fraterniflorus.

Figs. 20 & 21.

Convolvulus fraterniflorus Mackenzie & Bush, Rept. Mo. Bot. Garden 16:104. 1905.

Plants commonly hairy; peduncles ordinarily two or more in each axil, mostly shorter than the petioles; bracts sparingly hairy.

Mackenzie and Bush differentiated this species from *Convolvulus sepium* chiefly on the following characters: *Plant pubescent; peduncles angled and winged, ordinarily more than one in each axil and commonly shorter than the petioles; floral bracts cordate.* This combination of characters is not at all constant in our Indiana specimens. The specimens here considered as being this species were chosen mainly on the number and length of the peduncles. It is believed that a study of a larger number of specimens collected from a more extended range would show that this species is at the most worthy of but varietal distinction.

In moist situations.

Specimens examined: Clay Co. (Deam *37,782*); Greene Co. (Deam *37,773*); Hancock Co. (Mrs. Deam *9,073*; Deam *37,840*); Knox Co. (Deam *17,059A*).

10. Convolvulus repens.

Figs. 26 & 27.

Convolvulus repens L., Sp. Pl. 153. 1753.

Plants trailing, densely hairy; petioles mostly more than one-fourth as long as the blade; basal lobes of the leaves rounded; peduncles exceeding the petioles; bracts mostly cordate.

This species may be confused with some specimens of *Convolvulus spithamaeus* showing a tendency to twine, but it differs mainly in the degree of pubescence, length of plant and of petioles and in the shape of the leaves and bracts.

Along roadsides and in fields.

Specimens examined: Crawford Co. (Deam *8,434; 20,443;* Schneck in 1893); Harrison Co. (Deam *23,318*).

11. Convolvulus arvensis.

Figs. 22-25.

Convolvulus arvensis L., Sp. Pl. 153. 1753.

Plants smooth; leaves and flowers mostly smaller than in the other Indiana species; the bracts small and at some distance from the flower; peduncles much exceeding the petioles.

Along roadsides and in waste places generally.

Specimens examined: Dearborn Co. (Deam *12,444*); Jefferson Co. (Deam *13,408*); Lake Co. (Deam *2,339*); Marion Co. (Deam *6,956*); Putnam Co. (Grimes *2,142;* Wilson in 1893; Yuncker *1,356*); Tipton Co. (Grimes *945*); Wells Co. (Deam in 1897).

Explanation of Plates.

The sketches were made by laying the leaves on paper and drawing their outline. The drawings have been reduced so that they are now about one-half the natural size of the leaves.

PLANTS OF WHITE COUNTY—V.

LOUIS F. HEIMLICH, Purdue University.

In this paper 117 additional species and varieties of the White County, Indiana, flora are reported. This makes the total number of wild plants of the county reported by the author 387.

The author has spared no pains to make the following list as correct as possible. Practically all specimens were checked by C. C. Deam, Bluffton, Indiana. The Rosa species were identified by P. A. Rydberg, New York Botanical Garden. The Salix species were identified by C. R. Ball; the Malus and Crataegus species by W. W. Eggleston, both of the U. S. Department of Agriculture. The determination of numbers 661, 673, 677, 681, 682, 685, 686, 699, 700, 701, 703, 707, 710, 712, 739, 742, 745, 746, 747, 748, 753, 755, 763, 775, 776, 777, 780, 781, 782, 783, and 788 is authorized by the Gray Herbarium, Harvard University.

All species reported in this paper were collected in the central and northeastern part of the county. Species numbers 649 to 688 and numbers 827 and 828 were collected on April 21 and 23, 1922; numbers 690 to 735 were collected on May 27 and 28, 1922; numbers 739 to 825 were collected on August 30 and 31, and September 2 and 3, 1922. These numbers follow the species names and indicate the specimen numbers in the author's collection.

It is believed that the following species and varieties included in the list are new to the state or merit special reference.

Ranunculus hispidus Michx. var. *falsus* Fernald.
Rubus pergratus Blanchard.
Lespedeza capitata Michx. var. *stenophylla* Fernald & Bissell.
Solidago caesia L. var. *axillaris* (Pursh) Gray.
Xanthium pennsylvanicum Wallr.

Brief notes are attached to these and certain other interesting species in the general list below.

EQUISETACEAE.

Equisetum arvense L. Field horsetail. Nos. 651, 688. See fig. 1.

Equisetum kansanum Schaffn. (*E. laevigatum* A. Br.) No. 703. Smooth scouring rush.

TYPHACEAE.

Typha latifolia L. Broad-leaved cat-tail. No. 754

GRAMINEAE.

Digitaria sanguinalis (L.) Scop. (*Syntherisma sanguinale* (L) Dulac) No. 777. Large crab grass.

Panicum scribnerianum Nash. Scribner's panic grass. No. 699.

Setaria lutescens (Weigel) Hubbard. (*S. glauca* (L.) Beauv. of Gray's Manual, or the *Chaetochloa glauca* (L.) Scribn. of Britton and Brown). Common or yellow foxtail. No. 781. For revised nomenclature see Rhodora Vol. 18:232:1916.

Cenchrus tribuloides L. Sand-bur or bur-grass. No. 768.

Stipa spartea Trin. Porcupine-grass. No. 708. Grows on dry, sandy hill-sides.

Muhlenbergia sylvatica Torr. (*M.-M. umbrosa* Scribn. of B. & B.) Woodland dropseed. No. 780.

Phleum pratense L. Timothy. No. 784. Escaped and established plant of waste places and roadsides.

Eleusine indica Gaertn. Wire-grass or crab-grass. No. 783.

Eragrostis purshii Schrad. Pursh's love-grass. No. 775.

Eragrostis cilianensis (All.) Link. This is *E. megastachya* (Koeler) Link. Syn. *E. Major* Host. of Gray's Manual. Strong-scented lovegrass. No. 776.

Fig. 1. Field Horsetail *Equisetum arvense L.* A group of fertile stems growing in a moist sandy soil in south part of Reynolds, April 23, 1922.

Poa annua L. Annual or dwarf meadow-grass, or low spear-grass. No. 788.

Festuca octoflora Walt. Slender fescue-grass. No. 701.

Hordeum jubatum L. Squirrel-tail grass. No. 786.

CYPERACEAE.

Cyperus aristatus Rottb. (*C. inflexus* Muhl. of B. & B. ?) Awned cyperus. No. 746.

Eleocharis obtusa (Willd.) Schultes. Blunt spike-rush. No. 742.

Eleocharis capitata (L.) R. Br. Capitata spike-rush. No. 710. According to the Gray Herbarium this is the *E. tenius* (Wild) Schultes of the present manual.

Fimbristylis autumnalis (L.) R. & S. Slender fimbristylis. No. 745.

Scripus validus Vahl. American great bulrush. No. 749.

Hemicarpha micrantha (Vahl.) Pax. Common hemicarpha. No. 747.

ARACEAE.

Symplocarpus foetidus Nutt. Skunk cabbage. No. 669.

JUNCACEAE.

Juncus tenuis Willd. Slender or yard rush. No. 782.

Juncus acuminatus Michx. Sharp-fruited rush. No. 748.

Luzula campestris (L.) D.C. var. *bulbosa* Wood. Bulbous common wood-rush. (*Juncoides bulbosum* (Wood) Small of B. & B.) According to Deam this is the common form of Luzula in Indiana. He says it probably occurs in every county.

Fig. 2. White adder's tongue or white dog's-tooth violet. *Erythronium albidum* Nutt. Very plentiful in thickets and wooded areas on the western protected bluff near the mouth of Pike creek. April 21, 1922.

LILIACEAE.

Allium canadense L. Meadow garlic. No. 720.

Erythronium albidum Nutt. White adder's-tongue. No. 657. See figure 2.

Trillium sessile L. Sessile-flowered wake-robin. No. 656.

Smilax lasioneuron Hook. Carrion-flower. This species has usually been reported under the name *S. herbacea* L. var. *pulverulenta* Michx. See Bull. Torrey Club Vol. 43:417:1916. No. 732.

DIOSCOREACEAE.

Dioscorea villosa L. Wild yam-root or colic-root. No. 803.

IRIDACEAE.

Iris versicolor L. Larger blue flag. No. 702.

Sisyrinchium atlanticum Bicknell. Eastern blue-eyed grass. Reported last year by Deam as new to Indiana. Proc. Ind. Acad. Sci. 1921:102. Seems to be the common species near Reynolds. Nos. 690, 709.

ORCHIDACEAE.

Habenaria bracteata (Willd.) R. Br. Long-bracted orchid. Collected in low flat woods near mouth of Big Monon Creek. Rare. No. 717.

SALICACEAE.

Salix alba L. White or common or European willow. No. 828.

Salix cordata Muhl. Heart-leaved willow. Nos. 653♂, 827♀. In the Proc. Ind. Acad. Sci. 1918:447-450 I reported *S. missouriensis* Bebb. as occuring in Indiana—a new record, basing my report on the identification of a specimen by an authority. *S. cordata* Muhl., here reported is based on determinations by Mr. C. R. Ball. Considering *S. missouriensis* Bebb. as a distinct species, the author plans further investigations seeking to verify or disqualify its presence in White County.

Salix tristis Ait. Dwarf gray willow. No. 679♀.

URTICACEAE.

Urticastrum divaricatum (L.) Kuntze. (*Laportea canadensis* Gaud.) Canada nettle. No. 799.

SANTALACEAE.

Comandra umbellata (L.) Nutt. Bastard toad flax. Nos. 693, 195.

POLYGONACEAE.

Rumex obtusifolius L. Broad-leaved or bitter dock. No. 785.

AMARANTHACEAE.

Amaranthus blitoides S. Wats. Prostrate amaranth. No. 773.

CARYOPHYLLACEAE.

Arenaria lateriflora L. Blunt-leaved sandwort. No. 735.

Agrostemma githago L. Corn cockle or corn campion. No. 728.

PORTULACACEAE.

Portulaca oleracea L. Purslane. No. 774.

RANUNCULACEAE.

Ranunculus hispidus Michx. var. *falsus* Fernald. No. 661. This variety of the hispid buttercup is new to the state. The specimen was checked at the Gray Herbarium. Literature covering this group in Rhodora Vol. 22:30-31:1920 was not available. Specimen from near mouth of Pike creek.

Anemonella thalictroides (L.) Spach. Rue anemone or wind-flower. No. 655.

Anemone canadensis L. Canada anemone. No. 727.

Isopyrum biternatum (Raf.) T. & G. False rue anemone. No. 658.

MENISPERMACEAE.

Menispermum canadense L. Canada moonseed. No. 733.

BERBERIDACEAE.

Caulophyllum thalictroides (L.) Michx. Blue cohosh. No. 663.

LAURACEAE.

Benzoin aestivale (L.) Nees. Spicebush. Nos. 671, 824.

FUMARIACEAE.

Dicentra cucullaria (L.) Torr. Dutchman's breeches. No. 654. See figure 3. Minor Farm, near mouth of Pike creek, in a thicket at the edge of a pool.

CRUCIFERAE.

Cardamine douglassii (Torr.) Britton. Purple cress. No. 665.

Cardamine parviflora L. Small-flowered bitter-cress. No. 677.

Fig. 3. Dutchman's breeches. *Dicentra cucullaria* (L.) Torr. Common over bluffs north of mouth of Pike creek. Photograph shows a plant growing in sandy soil on the steep border of pool surrounded by a thicket. April 21, 1922.

CRASSULACEAE.

Penthorum sedoides L. Ditch or virginia stonecrop. No. 750.

SAXIFRAGACEAE.

Mitella diphylla L. Bishop's cap. No. 672.

Ribes cynosbati L. Prickly wild gooseberry. No. 670.

ROSACEAE.

Malus lancifolia Rehder. (*M. coronaria*, of manuals, in part.) Narrow-leaved crab apple. No. 815. Near mouth of Pike creek, a tree about 8½ inches in diameter, b.h., and from 25-30 feet high. Specimen collected Sept. 3, 1922. Tree at this time bearing an abundant crop of apples, 1¼ inches in diameter and ⅞ inch high, long peduncled.

Associated with *Malus ioensis* (Wood) Britton, No. 814, tree 2½ inches in diameter, 12 feet high, apples 1⅝ inches in diameter, 1⅜ inches high, short peduncled. Also associated with the next.

Crataegus mollis (T. & G.) Scheele. Red-fruited or downy thorn. No. 813. Fruit abundant, ⅞ inch in diameter.

Rubus pergratus Blanchard. Square blackberry. No. 712. This species has not been reported for Indiana. Rydberg in Flora of North America gives its distribution as Maine to Ontario to Iowa. Specimen taken from a sandy ridge at edge of a woods about one mile northeast of Reynolds. In flower May 27.

Rosa blanda Ait. Smooth or meadow rose. No. 730. This rose forms several hybrids. My No. 722, according to Rydberg, seems to be *R. blanda* Ait. X *R. carolina* L. *R. carolina* L. is the *R. humilis*, Marsh. of Gray's Manual. It is also the same as *R. perviflora* Ehrh., *R. pennsylvanica* Wang., *R. caroliniana* Michx., *R. pratensis* Raf.? It is *not* the *R. carolina* L. as described in either Gray's Manual or Britton and Brown's Illustrated Flora. These should both be *R. palustris* Marsh. For explanation see Rydberg: Contributions from the New York Botanical Garden, No. 220, Notes on Rosaceae, 1920, or the same in Bulletin of the Torrey Botanical Club 47:45-66, Mar. 10, 1920. My report of *R. humilis* Marsh. (Proc. Ind. Acad. Sci. 1920:224) in accordance with the above should in name be changed to *Rosa carolina* L.

Rosa rubiginosa L. Sweetbrier or eglantine. No. 731.

Prunus virginiana L. Choke cherry. No. 724. This is the species described in Gray's Manual. This species and *P. serotina* Ehrh., which are merged in Britton and Brown's Illustrated Flora, are considered distinct species by the writer.

LEGUMINOSAE.

Cassia marilandica L. Wild or american senna. No. 806. This species was reported for Indiana long ago (Coulter's Catalog, 1899, with references from many counties). Neither Britton and Brown, 2nd edi. 1913, nor Gray 7th edi. 1908, credit it to Indiana.

Baptisia leucantha T. & G. Large white wild indigo. No. 825. In flower Sept. 3, 1922.

Trifolium arvense L. Rabbit-foot, old-field or stone clover. No. 816. On steep, hard, dry bluff of Tippecanoe river just below bridge at Norway. Associated with *Campanula rotundifolia* L.

Cracca virginiana L. (*Tephrosia virginiana* (L.) Pers.) Catgut, wild sweet-pea or goat's rue. No. 763.

Lespedeza hirta (L.) Hornem. Hairy bush-clover. No. 763.

Lespedeza capitata Michx. var. *stenophylla* Fern. & Biss. This variety is new to the state. The variety is described by Fernald and Bissell in Rhodora Vol. 14:92:1912. The specimen here reported was checked at the Gray Herbarium. Specimen taken from along the Pennsylvania railroad, east of Reynolds, growing in dry, sandy soil. No. 739.

Vicia americana Muhl. American or purple vetch. No. 721.

Strophostyles helvola (L.) Britton. Trailing wild bean. No. 789.

Falcata comosa (L.) Kuntze. (*Amphicarpa monoica* Ell.) Hog peanut. No. 798.

LINACEAE.

Linum virginianum L. Wild or slender yellow flax. No. 753.

POLYGALACEAE.

Polygala verticillata L. Whorled milkwort. No. 770.

BALSAMINACEAE.

Impatiens biflora Walt. Wild touch-me-not. No. 800.

VITACEAE.

Vitis aestivalis Michx. Summer or pigeon grape. No. 821. In a low, moist woods near mouth of Big Monon creek. The vines reached the high tree-tops. The main stem measured 19 inches in circumference.

Vitis vulpina L. Riverside or sweet-scented grape. No. 808.

CISTACEAE.

Helianthemum bicknellii Fernald. (*H. majus* B.S.P. of Gray's Man. *Crocanthemum majus* (L.) Brit. of B. & B.) Hoary frostweed. No. 707.

VIOLACEAE.

Viola sororia Willd. Wooly blue violet. Nos. 652, 660.

Viola scabriuscula Schwein. Smoothish yellow violet. No. 662.

Viola primulifolia L. var. *villosa* A. Eaton. No. 163. The following is an extract of a letter received from Ezra Brainard in answer to his receipt of my leaflet "The Primrose-leaved Violet in White County, Proc. Ind. Acad. Sci. 1914:213-217." "The drawing of your specimens seems to make them Eaton's var. *villosa*, a form commonly found in the South as far West as Calcasien County, La. (lat. 30½°). Its occurrence in Ind. Lat. 40° 35′, about 700 miles further north, is surprising. This pubescence in your plant may, however, be an instance of the general law that low temperature and high humidity, as in your small mucky bog, favor pubescence, while high temperature and low humidity tend to do the opposite." See Brainerd, Violets of North America, Vt. Agr. Exp., Sta. Bul. 224: Dec., 1921, p. 87, also pp. 64 and 65. Pitt. 3:315 May, 1898.

ONAGRACEAE.

Ludwigia palustris L. Marsh purslane or false loose strife. No. 741.

HALORAGIDACEAE.

Proserpinaca palustris L. Mermaid-weed. No. 678.

UMBELLIFERAE.

Zizia aurea (L.) Koch. Early or golden meadow parsnip. No. 696.

Daucus carota L. Wild carrot. No. 790.

ERICACEAE.

Vaccinium vacillans Kalm. Low blueberry. No. 685.

GENTIANACEAE.

Gentiana saponaria L. Soapwort gentian. No. 771.

CONVOLVULACEAE.

Cuscuta gronovii Willd. Gronovius' dodder. No. 755. On willows.

POLEMONIACEAE.

Phlox pilosa L. Downy or prairie phlox. No. 698.
Phlox bifida Beck. Cleft phlox. No. 684.

HYDROPHYLLACEAE.

Hydrophyllum virginianum L. Virginia waterleaf. No. 729.

BORAGINACEAE.

Lappula virginiana (L.) Greene. Virginia stickseed. No. 807.
Mertensia virginica (L.) DC. Virginia cowslip. No. 659.
Lithospermum arvense L. Corn gromwell. No. 681.
Lithospermum canescens (Michx.) Lehm. Hoary puccoon. No. 682.

LABIATAE.

Scutellaria lateriflora L. Mad-dog or blue skullcap. Nos. 751, 792, 801.
Nepeta hederaceca (L.) Trevisan. Ground ivy. No. 650.
Mentha spicata L. Spearmint. Nos. 760, 796.

SCROPHULARIACEAE.

Mimulus ringens L. Square-stemmed monkey-flower. Nos. 743, 795.
Gratiola virginiana L. Clammy hedge-hyssop. No. 711.
Veronica scutellata L. Marsh or skullcap speedwell. No. 713.
Veronica peregrina L. Purslane speedwell. No. 705.
Afzelia macrophylla (Nutt.) Kuntze. Mullen foxglove. No. 812.

BIGNONIACEAE.

Bignonia radicans L. (Tecoma) Trumpet-vine. No. 819. Growing in low, moist ground near mouth of Big Monon creek.

CAPIFOLIACEAE.

Triosteum aurantiacum Bicknell. Scarlet-fruited horse-gentian. No. 726.

CAMPANULACEAE.

Campanula rotundifolia L. Harebell or blue bells of Scotland. No. 817. Many-flowered form. On steep, dry bluff of the Tippecanoe river just below the bridge at Norway. Associated with *Trifolium arvense* L.

COMPOSITAE.

Eupatorium purpureum L. Joe-pye or trumpet-weed, tall or purple boneset. See Rhodora Vol. 22:64.
Eupatorium urticaefolium Reichard. White snake-root. No. 791.
Solidago caesia L. Blue-stemmed or wreath golden-rod. No. 802.
Solidago caesia L. var. *axillaris* (Pursh) Gray. No. 822.
This variety has not been reported for Indiana. It seems to be an extremely doubtful variety, being perhaps only a simple stemmed form of the species. Britton and Brown do not recognize the variety, nor do they even make mention of the variety *paniculata* of Gray. According to Deam most of the Indiana specimens do not agree with the description of the species as given in Gray, but more nearly with the variety *paniculata.* The variety is here reported for the information of other collectors.
Solidago rigida L. Stiff or hard-leaved golden-rod. No. 740.

Antennaria fallax Greene. Nos. 673, 686. See figure 4. Reported by Deam for Indiana, Proc. Ind. Acad. Sci. 1914. Both of my specimens were checked by the Gray Herbarium. *S. ambigens* Fernald is a synonym. Neither name is listed in Britton and Brown, Illustrated Flora, 2nd. edi.

Fig. 4. Cat's-foot or everlasting. *Antennaria fallax* Greene. A part of a large colony of these plants growing on the southeastern edge of a sand hill about one-fourth mile east of Reynolds. April 23, 1922.

Xanthium pennsylvanicum Wallr. Pennsylvania clotbur. No. 793. This is a new name in the list of plants for Indiana. Perhaps most of the reports for *X. canadense* Mill. should be referred to this species. The genus has long been in an uncertain condition. For the new treatment of the genus see North American Flora Vol. 33:37-44: 1922.

Heliopsis helianthoides (L.) Sweet. Ox-eye or false sunflower. No. 810.

Rudbeckia laciniata L. Tall or green-headed cone-flower. No. 823.

Ridan alternifolius (L.) Britton. Wing-stem or yellow iron weed. No. 809.

Helenium autumnale L. False or swamp sunflower. No. 757.

Tanacetum vulgare L. Tansy. No. 761. This plant is growing wild in several places in the county according to recent observations. (See Proc. Ind. Acad. Sci. 1920:223.)

THE USTILAGINALES OF INDIANA III.[1]

H. S. JACKSON, Purdue University Agricultural Experiment Station.

The following notes on the smuts of Indiana are presented at this time as the second supplement to the paper bearing the same title which was published in the Proceedings of the Indiana Academy of Science for 1917, pp. 119-132. The first supplement was included in the Proceedings for 1920, pp. 157-164.

In the two previous papers a total of 57 species have been recorded for the state. The present paper includes records for seven additional species, bringing the total number found in Indiana to 64. Additional notes are included on some of the previously recorded species. As in the previous papers each species is given a number and these are consecutive for the three papers. Unless otherwise stated the collections were made by the writer.

NOTES ON SPECIES PREVIOUSLY RECORDED.

33. ENTYLOMA COMPOSITARUM Farl.

On CARDUACEAE:

Ratibida pinnata (Vent) Barnh. (*Lepachys pinnata* (Vent) Torr. & Gray.) Bayle's Mills, Tippecanoe Co., June 12, 1922, with H. H. Whetzel.

The collection reported in the 1917 list on *Ambrosia elatior* L. has been transferred to *Entyloma polysporum* cf. 37. No collections on Ambrosia referrible to *E. compositarum* have yet been made in Indiana.

37. ENTYLOMA POLYSPORUM (Peck) Farl.

On AMBROSIACEAE:

Ambrosia elatior L., LaFayette, July 2, 1889, J. C. Arthur; Ladoga, July 27, 1920, P. J. and H. W. Anderson.

Ambrosia trifida L., West Lafayette, August 21, 1916; Dayton, September 2, 1920.

In the 1917 report it was stated that, while this species was listed from Indiana by Clinton (N. Am. Flora 7:62. 1906), we had seen no specimens. The above collections have since been encountered. I am indebted to Dr. G. P. Clinton for the identifications. The collection first mentioned was previously recorded as *E. compositarum* but should be transferred to this species.

SPECIES NEW TO INDIANA.

USTILAGINACEAE.

58. SOROSPORIUM ELLISII Wint. Hedwigia 22:2. Ja. 1883.—Bull. Torrey Club. 10:7. Ja. 1883.

On POACEAE:

Andropogon virginicus L., One mile west of French Lick, October 5, 1921.

Schizachyrium scoparium (Michx.) Nash., Thayer, Newton Co., May 1921 and September 29, 1921.

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[1] Contribution from the Botanical Department of the Purdue University Agricultural Experiment Station.

"Proc. 38th Meeting, 1922 (1923)."

In this species the entire inflorescence is reduced to a smutty mass of spores as distinguished from the next following species which attacks only the individual ovaries. In the original description, this species was confused with another on *Aristida dichotoma*.[2]

59. SOROSPORIUM EVERHARTII Ellis & Gall. Jour. Myc. 6:32. 1890.

On POACEAE:

Andropogon virginicus L. One mile west of French Lick, October 5, 1921.

60. SPHACELOTHECA OCCIDENTALIS (Seym.) Clinton Jour. Myc. 8:141. 1902.

Soroporum Ellisii occidentalis Seym.; Ellis & Ev. N. Am. Fungi *2,265*. 1889.

On POACEAE:

Andropogon furcatus. Muhl. In flat sterile place in woods on south side of Lake Maxinkuckee, Marshall County, September 14, 1921. C. C. Deam, *34,722*.

This species occurs in the individual ovaries of the grass and is doubtless not uncommon, but has not before been recorded so far east.

61. USTILAGO OXALDIS Ellis & Tracy, Jour. Myc. 6:77. 1890.

On OXALIDACEAE:

Oxalis stricta L. Near English, May 24, 1922; near Huntingburg, May 25, 1922.

This is a species of wide distribution in the eastern half of the United States. The sori occur in the seeds, the affected ovaries differing only slightly from the normal. Usually all the seed of diseased plants are affected.

TILLETIACEAE.

62. DOASSANSIA MARTIANOFFIANA (Thuem.) Schrot. Krypt. Fl. Sches. 3[1]:287. 1887.

Protomyces martianoffianus Thuem. Bull. Soc. Nat. Mosc. 53[1]:207. 1878.

On ZANNICHELLIACEAE:

Potamogeton sp. Edge of Bass Lake, Starke County, June 18, 1921.

An inconspicuous species forming yellowish white spots on the leaves which later become reddish brown.

63. ENTYLOMA SEROTINUM Schroet. Bietr. Biol. Pfl. 2:437. 1877.

On BORAGINACEAE:

Mertensia virginica (L.) DC. Near Harrodsburg, May 7, 1921. J. M. Van Hook *3,865*.

64. TILLETIA CORONA Schrib. Tracy & Earle, Bull. Torrey Club. 23:210. 1896.

On POACEAE:

HAMALOCENCHRUS VIRGINICUS (Willd.) Britt. Northeast of Fairmount, October 3, 1915. C. C. Deam *19,314;* One mile southwest of French Lick, October 5, 1921.

This species causes rather conspicuous enlarged and deformed ovaries, only occasional ones in the inflorescence being infected.

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[2] Cf. Jackson, H. S. Sorosporium Ellisii Wint., a Composite species. Bull. Torrey Club. 35: 148. 1908.

RECENT INDIANA WEEDS.[1]

ALBERT A. HANSEN,

Purdue University Department of Agricultural Extension.

New weeds appear practically every year in Indiana, usually through the medium of impure seed. Occasionally the newcomers flourish for a while, then practically disappear. Some species, however, make themselves thoroughly at home and frequently become so aggressive that they are a source of considerable loss and annoyance to the farmer. The great majority of our troublesome weeds are introduced species; for instance, only two of the nineteen species designated as noxious in the Indiana seed law are native plants.

The species considered in this paper include, (1) plants that are known to be troublesome elsewhere but have not been previously recorded as occurring in Indiana by authorities on the distribution of plants, (2) plants that have not been previously reported as troublesome weeds. This report covers the period from October 1, 1921, to October 1, 1922.

For verifying identifications, acknowledgment and thanks are due F. V. Coville, A. S. Hitchcock, and S. F. Blake, all of the United States Department of Agriculture, J. N. Rose of the Smithonian Institution and B. L. Robinson of the Gray Herbarium.

Perennial sow thistle (*Sonchus arvensis* L.). Found growing luxuriantly on the farm of Harry Warr, Brook, Indiana. Mr. Warr considers it a "very bad weed with roots that go down three feet."

The discovery of perennial sow thistle in Indiana is of importance since this species is one of the most troublesome weeds in America, particularly in the Red River Valley of Minnesota and North Dakota and in adjacent Canada. The plant causes greatest damage where a one-crop system of grain farming is practiced, consequently it is not thought that the species can become as troublesome in Indiana on account of the diversified farming practices that prevail. Nevertheless it is a noxious weed that should be guarded against.

Spotted knapweed (*Centaurea maculosa* Lam.). A well-established patch of spotted knapweed was found on the Lofland farm near Romney, Tippecanoe County. The occurrence of this species in Indiana is noteworthy since it is a close relative of the black knapweed, *Centaurea nigra*, considered a serious grassland weed in Europe and recently troublesome in New York.

Perennial peppergrass or hoary cress. (*Lepidium draba* L.) Found in LaGrange County. During recent years this species has become extremely troublesome in Utah, California, Colorado and other western states. The following statement is quoted from Bulletin 264 of the Colorado Agricultural Experiment Station.

"Recently the perennial peppergrass has become of such frequent occurrence in Colorado that unless prompt action be taken for its

[1] Contribution from the Botanical Department (Extension Division) of the Purdue University Agricultural Experiment Station.

control it is almost certain to spread itself over most of the cultivated areas of the state. During the past season this station has received numerous urgent appeals for some definite advice concerning methods for controlling this pest."

Mexican clover. (*Richardia scabra* L.) A new weed that is appearing in abundance in fields in the northeastern part of Henry County. It is a very common weed in the southern states, particularly in the gulf states, although it rarely becomes very troublesome. The common name is misleading since the plant is not a clover but is a member of the Rubiaceae.

Lawn pennywort. (*Hydrocotyle rotundifolia* Roxb.) Recently reported as a new lawn weed in America in Department of Agriculture, Circular 165. Its distribution was reported as the District of Columbia, locally in Pennsylvania, and near Louisville, Kentucky. The species was discovered as a serious lawn pest in Evansville, Indiana, where it presents a difficult lawn problem. It is a native of southern Asia.

Welted thistle. (*Carduus crispus* L.) Occurs locally in the eastern states. The species was found established in Union County, Indiana. It is a perennial and a native of Europe and Asia.

Western brome grass. (*Bromus carinatus* Hook and Arn.) A native western perennial that is common on the Pacific Coast, was found on the farm of Smith Brothers, Middlebury, Indiana. Since immediate measures were taken for the destruction of the several patches found it is not likely that the species will persist.

Phacelia. (*Phacelia purshii* Buckl.) A native annual that is causing much damage to oats, clover and wheat in Rush and Wayne Counties. In one part of Rush County about 500 acres of clover and wheat were seriously infested during the spring of 1922. The plant seems to choke out the crop, causing an uneven stand. No record can be found of this species causing damage as a field weed in other sections of the United States.

Bermuda grass. (*Capriola dactylon* (L.) Kuntze.) Bermuda grass, ordinarily considered to be a weed in the southern states only, is locally troublesome throughout Indiana, where it is frequently mistaken for quack grass. Although one of the worst weeds in the south, the species is at the same time a valuable lawn and pasture plant in the southeastern states. Shallow fall plowing followed by a good shade crop should kill Bermuda grass.

Johnson grass. (*Holcus halepensis* L.) The statement is frequently heard that Johnson grass cannot persist north of the Ohio River. The plant has been established in Indiana for a number of years and is known to be troublesome as far north as Vigo County, particularly in the vicinity of Terre Haute where it covers about five hundred acres of land. The farmers contend that it is one of the worst weeds in the county. It is said to have been introduced into Vigo County by means of western hay. Johnson grass is also troublesome in Scott County.

Gum Plant. (*Grindelia robusta* Nutt.) A native western species that occurs principally along the California coast, has been reported

as growing in sandy land near Ontario, LaGrange County. Specimens have been collected by C. C. Deam.

Wild Corn. (*Andropogon sorghum*, var. *drummondii* Hack.) A serious problem in corn fields on overflow land along the Ohio and Wabash Rivers in the southwestern part of the state, particularly in Vanderburg and Posey Counties.

CONCLUSION.

The Purdue Agricultural Experiment Station desires to keep in touch with new plants in Indiana that are apt to prove troublesome. Specimens of strange plants that exhibit weedy tendencies will be welcomed. It is thought that a great deal of trouble and expense can be saved to the farmers of the state if prompt action is taken as soon as new weeds are noted.

WILD CORN, A SERIOUS WEED IN INDIANA.[1]

ALBERT A. HANSEN, Purdue University Agricultural Experiment Station.

Wild corn is a member of the sorghum tribe that causes heavy losses on overflow land along the Ohio and Wabash Rivers in Posey and Vanderburgh counties, Indiana, and along the Ohio River in Henderson County, Kentucky.

The problem presented is very unusual. The seeds, which are produced in large numbers, are carried by the flood water. When the water subsides, the seeds are left on the soil, ready to germinate with the corn crop. The young wild corn plants resemble corn seedlings so closely that recognition is difficult and they become large plants before they can be identified. The damage done is so heavy that in some cases infested corn crops have been left unharvested. The seriousness of the situation is indicated by the fact that a request for assistance in controlling this weed was recently received from forty-six farmers residing in Kentucky and Indiana. They represented a total of 21,186 acres of corn land 25.9 per cent or 5,487 acres of which was damaged by wild corn during 1921. During a weed survey recently conducted by the Agricultural Extension Department of Purdue University, wild corn was reported as the second worst weed in Posey County by County Agent W. E. Shrode.

Wild corn has been identified as *Andropogon sorghum drummondii* Hack, a wild variety of common sorghum. The plant is said to have been introduced from Africa by the early slave traders. It spread in the southern coastal states, particularly in Louisiana and Mississippi, but it was rarely found further north. In its southern range the plant was commonly called chicken corn. Although classed as a weed, it was sometimes used as a source of wild hay and for fall pasture. The seeds were also gathered occasionally for chicken feed. With the introduction

[1] Contribution from the Botanical Department (Extension Division) of the Purdue University Agricultural Experiment Station.

of cultivated sorghum and the consequent spread of the sorghum midge, wild corn almost disappeared throughout its range, due to the ravages of the insect. The existence of the plant in large areas along the Ohio river in Kentucky was unsuspected until announced by the writer a year ago.[2] The occurrence of wild corn as a serious weed problem along the Ohio and Wabash rivers in Indiana is an important economic problem. That the species is persisting is probably explained by the fact that Indiana is so far north as to be out of the range of the sorghum midge. Although a native of a warmer climate, the plant seems to be thoroughly acclimated in its northern home.

Controlling wild corn is far from an easy job. In Posey County the only successful control method practiced is thorough cultivation, including regular hoeing as soon as the weed is large enough to be recognized. One difficulty is that chance seedlings spring up throughout the growing season in spite of the most diligent hoeing. Some farmers reduce the damage considerably by delaying planting in the spring until after most of the wild corn seeds have sprouted. The young plants are then destroyed by plowing and preparing the seed bed for corn. There seems little hope for controlling the weed by crop rotation since corn is practically the only crop the farmers will grow on the overflow land.

A solution that suggests itself is the introduction and acclimatization of the sorghum midge. If this could be done, the wild corn would probably soon disappear since the midge prevents the production of viable seeds and wild corn is an annual plant, depending entirely upon seeds to reproduce. The introduction and acclimatization of the sorghum midge is a dangerous experiment, however, since the insect might attack the sorghum crop, which is worth about $1,000,000 annually in Indiana.

Surface cultivation in the fall in order to induce the germination of the seeds of wild corn seems to offer little hope as a remedy since most of the infested land is subject to overflow during late spring and early fall, and seeds are scattered over the fields during each overflow.

Since wild corn is an annual, it is possible that if all the plants were kept from seeding throughout a single season, the pest would disappear, providing none of the seeds remained viable in the soil during the second winter. Large scale co-operation of this type among farmers is theoretically possible but practically almost impossible. Until further knowledge is secured, late planting and thorough cultivation will have to be depended on as the best control measures available.

In addition to the economic phase of the subject, wild corn presents a problem of considerable interest to the plant ecologist.

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[2] Chicken Corn, an Unusual Weed, Found Growing in River Lowlands in Kentucky. Weekly News Letter, U.S.D.A. June 29, 1921.

POLYEMBRYONY IN CERTAIN NUT BEARING PINES.

D. M. MOTTIER, Indiana University.

In seeds of nut bearing pines, "pinyon nuts", used for class study, the presence of two embryos in individual seeds has been observed from time to time. During the autumn of 1922, a member of the class called my attention to two well developed embryos of nearly the same size in a seed, probably of *Pinus edulis* Englemann, given him for study. Closer examination revealed the fact that in this seed three other smaller embryos were also present, making five in all, as shown in figure 1. The three smaller embryos are large enough to be recognized by the unaided eye. The figure represents the five embryos in proper proportion. In the three smaller embryos no indication of cotyledons could be recognized with the hand lens. The two larger embryos seemed to be mature as regards the differentiation of parts. The one near the chalazal end is perceptibly larger. In cases in which only one embryo is present

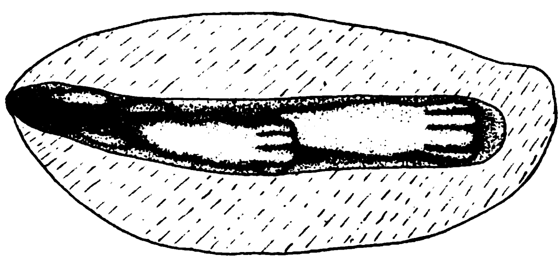

Fig. 1. One-half of endosperm of *Pinus edulus*, showing the five embryos in position. x 6.

in the mature seed, the length of the embryo is almost equal to the length of the endosperm.

As is well known, polyembryony in the genus Pinus results from the cleavage of the pro-embryo into four embryos, all of which tend to develop, but owing to competition, embryonal selection results, and only one embryo, as a rule, matures in the seed. If only one egg be fecundated, we have mono-zygotic cleavage polyembryony. But if two or more eggs are fecundated, as frequently happens in some species of pines (*P. laricio*), we have what may be termed poly-zygotic cleavage polyembryony. In Gymnosperms in which the embryonal cells do not separate, and one embryo develops from each fecundated egg, polyembryony can result only from two or more fecundated eggs. This is simple poly-zygotic polyembryony.

In cases of poly-zygotic cleavage polyembryony in Gymnosperms, it is very evident that among the numerous embryos that begin development, with apparently an equal start, the struggle for supremacy is very intense. The instance of figure 1 shows that the two larger were almost potentially equal, the one being unable to crowd out the other. Each, however, is about one-half the size of the single embryo normally

"Proc. 38th Meeting, 1922 (1923)."

surviving in the mature seed. Both were unable to obliterate completely the three smaller embryos by the time the seed matured.

What it is that enables the successful embryo or embryos to win out in the struggle, assuming that two or more have an equal start, can only be conjectured.

The writer has conducted a class in the embryology of Gymnosperms for many years, using chiefly *Pinus laricio*, and of the numerous pro-embryos in various stages of growth observed, the one which apparently had the upper hand seemed to be the one plunged more deeply chalazal-wards in the endosperm, but cases have been observed in which the deepest was not the largest.

Time and again it has been observed in microtome sections that embryos were entangled among the suspensors, some pointing directly towards the micropyle and growing in that direction. It would seem reasonable to assume that such embryos would be as well nourished as those growing downward into the endosperm.

For an admirable presentation of polyembryony in Gymnosperms the reader is referred to the following papers by John T. Buchholz: Suspensor and early embryo of Pinus. Bot. Gaz. 66: 185-228, 1918; Polyembryony among Abietineae. Bot. Gaz. 69: 153-167, 1920; Embryo development and polyembryony in relation to the phylogeny of conifers. Amer. Jour. Bot. 7: 125-145, 1920.

PHYTOPHTHORA ROT OF TOMATO, EGGPLANT, AND PEPPER.[1]

JAMES B. KENDRICK, Purdue University Agricultural Experiment Station.

A Phytophthora rot, apparently identical with buckeye rot of tomato appeared in epidemic form in an experimental plot of tomatoes at Lafayette, Indiana, August 1-3, 1921. The disease continued throughout the summer and destroyed about 40 per cent of the tomato fruits. A few weeks later, a very similar disease developed on eggplant and sweet pepper fruits growing adjacent to the tomatoes, and from all of these, the same Phytophthora was repeatedly isolated. With the Phytophthora isolated from tomato, successful inoculations were secured on eggplant and pepper fruits. The organism was repeatedly isolated from inoculated eggplant and pepper fruits. So far as has been determined, this disease has not been previously reported in Indiana under field conditions.

History.—The genus Phytophthora contains a number of species which are separated by apparently minor and none too stable differences. Rosenbaum[2] made an extensive comparative study of nine described species of Phytophthora and presented a tentative table for the separation of species based on his studies.

Sherbakoff[3] working in Florida, described a buckeye rot of tomatoes in 1917 which he attributed to an undescribed species of Phytophthora to which he gave the name, *P. terrestris*. Using the fungus isolated from tomato, he inoculated tomatoes, sweet peppers, watermelon fruit, lemons, and tubers of Irish potatoes and secured infection in every case.

Late blight of potatoes, caused by *Phytophthora infestans*, has been reported on tomatoes in West Virginia by Giddings.[4] It occurred on leaf, stem and fruit, causing a rot of the fruit. He reports serious losses due to blighting of the plants before many fruits were set. The organism, according to Giddings, is morphologically identical to *P. infestans* which causes a serious blighting of potatoes.

In 1915, Haskell[5] while stationed in Dutchess county, New York, observed a disease on eggplant fruit pedicles and calyces and a decay of a few of the younger fruits. The eggplants were growing adjacent to a field of potatoes which were badly infected with *P. infestans*. A comparison of the organism causing the disease on the eggplants with *P. infestans* from the potatoes showed that the two were identical.

[1] Contribution from the Botanical Department of Purdue University Agricultural Experiment Station, Lafayette, Indiana.

The writer wishes to express his appreciation to Dr. Max W. Gardner for helpful suggestions and criticisms.

[2] Rosenbaum, J. Studies of the Genus Phytophthora. Jour. Agr. Res. 8:233-276, 13 fig., 7 pl., 1917.

[3] Sherbakoff, C. D. Buckeye rot of tomato fruit. Phytopath. 7:119-129. 5 fig., 1917.

[4] Giddings, N. J. Potato and tomato diseases. West Virginia Agr. Exp. Sta. Bul. 165, 18-19. 1917.

[5] Haskell, R. J. Phytophthora infestans on eggplant in the United States. Phytopath. 11:504-505. 1917.

"Proc. 38th Meeting, 1922 (1923)."

Leonian[6] recently described a stem and fruit blight of peppers caused by a species of Phytophthora which he named *P. capsici*. Peculiar tuberous growths on the mycelium resembling sporangia were considered a distinctive morphological character of this species. No reference is made to Sherbakoff's work[7] on *P. terrestris*.

The morphological characters of the fungus causing the disease in Indiana do not agree with either *P. infestans* (Mont.) DeBary, or *P. capsici* Leonian, but do agree very closely with *P. terrestris* Sherb. The symptoms of the disease on tomato are very similar to the symptoms of buckeye rot of tomato as described by Sherbakoff[7], and therefore it seems likely that the causal organism of the disease of tomatoes, eggplants and peppers in Indiana is *P. terrestris*.

Distribution and Economic Importance.—Buckeye rot of tomatoes, caused by *P. terrestris* has been reported from Florida[7] where it has caused serious losses due to the rotting of the fruits, especially those touching or very near the ground. In 1919, Weimer observed buckeye rot on tomatoes in the U. S. Department of Agriculture experimental field plots at Arlington Farms, Virginia. In 1920, Jehle[8] reported the loss from buckeye rot of tomatoes to be one to two per cent in the coastal plain counties of North Carolina. Pritchard[9] the same year reported a 0.5 per cent loss on the experimental farms at Arlington, Va. It was also reported as causing loss of lower fruits in greenhouses in Indiana[9].

In 1921, Sherbakoff[10] reported the loss in Tennessee from buckeye rot to be approximately ten per cent, and Pritchard[10] again reported the disease prevalent on the experimental farm at Arlington, Va. The rot was reported on tomatoes shipped from Texas and Mexico in 1919 in the plant disease survey bulletin.

Buckeye rot is primarily a tropical or subtropical disease. It often causes serious losses in greenhouses in the north where tomatoes are grown under warm humid conditions.

It is possible that the organism causing buckeye rot may be carried from one locality to another in the soil on the roots of young plants. In 1920, about a hundred tomato plants grown in Georgia were put out in the experimental field at Lafayette, Ind. In 1921, tomatoes were grown on this same soil and it was in these tomatoes that the epidemic of buckeye rot occurred. Tomatoes were again grown there in 1922, but no buckeye rot developed, possibly due to drier weather conditions.

Symptoms.—The disease as observed in Indiana affects only the fruits of the host plants. The lesion first appears on the green tomato fruits as a very small web or lace-like blotch five to ten mm. in diameter. (Fig. 1, A). These spots look like a few dark-brown tan-

[6] Leonian, Leon H. Stem and fruit blight of peppers caused by Phytophthora capsici sp. nov. Phytopath. 12:401-408, 2 fig., 1922.

[7] Sherbakoff, *loc. cit.*

[8] Haskell, R. J. and Wood, Jessie. Diseases of field and vegetable crops in the United States in 1919. U.S.D.A. Plant Disease Bul., Supplement 10, p. 217, June 1, 1920.

[9] Haskell, R. J. and Wood, J. I. Diseases of field and vegetable crops in the United States in 1920. U.S.D.A. Plant Disease Bul., Supplement 16, page 224, June 1, 1921.

[10] Coons, G. H. Diseases of field and vegetable crops in the United States in 1921. U.S.D.A. Plant Disease Bul., Supplement 22, p. 328-329, July 20, 1922.

gled threads embedded in the epidermis of the fruit. This develops rapidly into a dark water-soaked spot, and in a few days may increase to 20 to 30 mm. in diameter. Several spots often occur on the same fruit and later coalesce into one large spot. (Fig. 1, B). As the rot progresses dark-brown concentric rings or zones are formed in the diseased area, giving it the buckeye appearance. (Fig. 1, C). The fungus

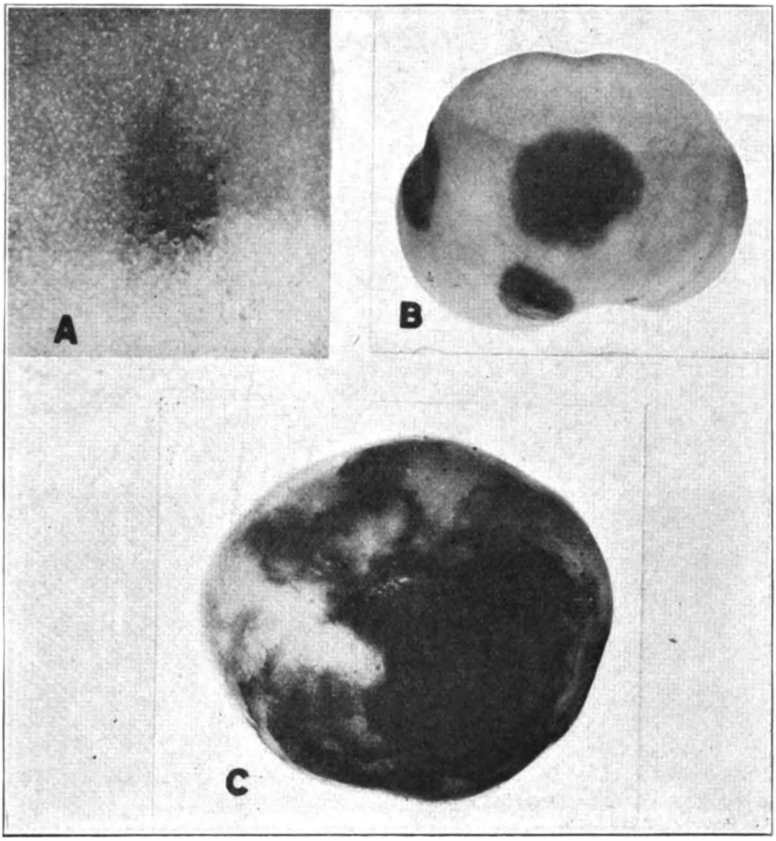

Fig. 1. *Phytophthora terrestris* on tomato fruit. *A*. Incipient infection showing the dark brown web- or lace-like early stage of the lesion (X3). *B*. Lesions three to four days older than the lesion in *A*. *C*. A later stage showing the concentric brown markings in the diseased area.

does not cause a marked disintegration of the tissues. The host cells are killed, but the tissue involved is firm until a later stage of the disease, by which time saphrophytic bacterial invaders have entered and caused a soft rot of the fruit.

On mature tomato fruits, the disease causes a premature ripening and decay. No young lesions were observed on ripe fruits, but young lesions were observed on green fruits of all sizes. From these observa-

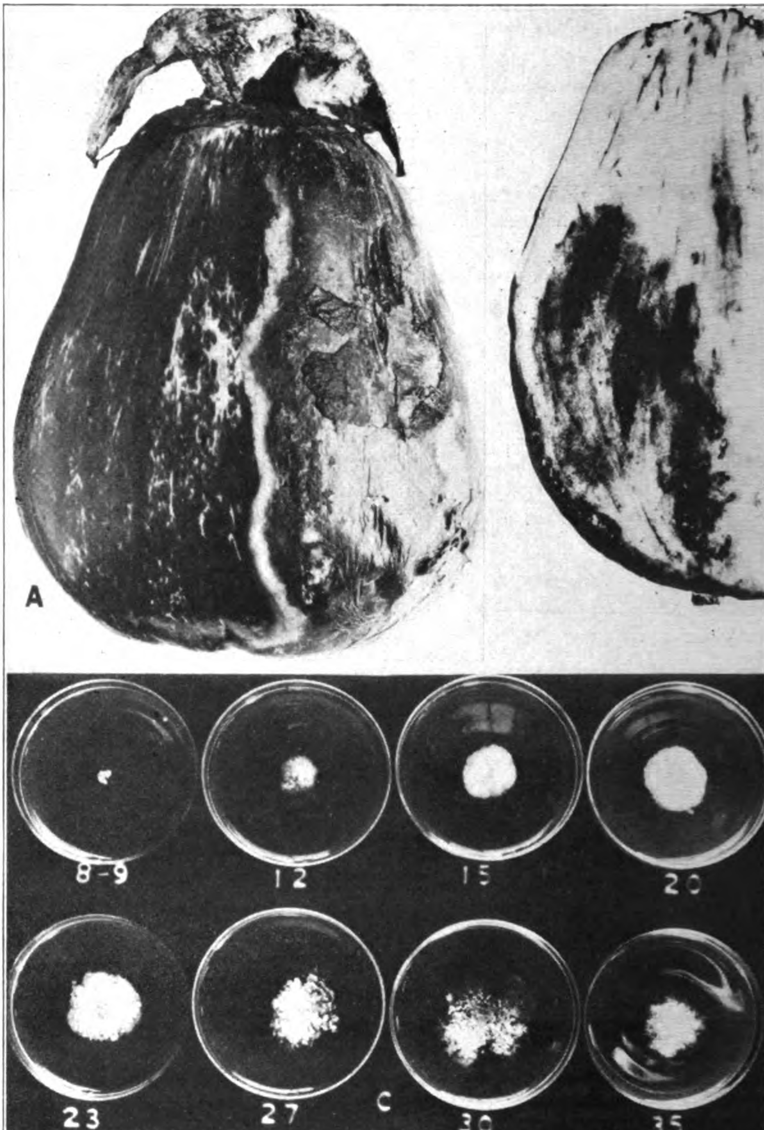

Fig. 2. *A*. Rot on eggplant fruit induced by inoculation with the Phytophthora isolated from tomato. The diseased fruit has separated from the stem, a condition which is characteristic of the disease on eggplant. *B*. Longitudinal section of an infected eggplant showing the darker infected tissue and discoloration of the vascular bundles over the entire surface, especially at the stem-end. *C*. Growth of the fungus after nine days incubation at different temperatures. The numbers denote the temperature on the centigrade scale.

tions, it seemed likely that the bulk of the infection took place when the fruits were green.

On the eggplant, the fungus produces a dark-brown spot on the fruit with a conspicuous light-colored border. (Fig. 2, A). When the fruit is cut open, the fungus is found to extend well into the flesh as evidenced by the dark-brown discoloration of the tissues. (Fig. 2, B). The fungus appears to advance most rapidly in the vascular bundles since these show as dark strands running out from the badly discolored area. (Fig. 2, B). Affected fruits drop from the stem prematurely and in no case was a fruit observed to remain on the stem after more than one-half the fruit had become involved. This premature dropping of the fruit from the stems is attributed to the invasion of the fibro-vascular tissues at the stem-end and a stimulation of the abscission process.

The symptoms on pepper are not as pronounced as on either tomato or eggplant. The first symptom is a small dark-green water-soaked spot. The lesion enlarges rapidly and before the rot involves one-half of the fruit, it drops from the plant. The somewhat wilted pedicels remain attached to the fruits and when cut longitudinally, show discolored vascular bundles. When these pedicels were incubated in a damp chamber, a fungus similar to the one isolated from the fruits grew out of them. The fungus penetrates the pedicels of the pepper fruits but apparently not the branches of the plant. In the eggplant, the fungus apparently does not invade the pedicel at all. In the case of peppers only the green fruits are susceptible.

The Fungus.—The fungus was readily isolated from infected tomato, eggplant and pepper fruits by planting small blocks of infected tissue, cut out aseptically, in poured plates of potato agar. In practically every case, a white, rather dense, spreading and somewhat tufted fungus developed from the tissue plantings. The organism grows well on potato agar, which has been used almost entirely in the laboratory cultural work.

The mycelium is at first continuous, but later becomes sparingly septate and branched. Peculiar distortions or tuberous outgrowths are very common on the mycelium in old cultures. Conidia are produced in cultures on potato agar in four to six days, but not abundantly. In Petri dish cultures on sterilized sugar beet and radish leaves in water, an abundance of conidia are produced in three days. Conidia are usually borne terminally, but often are intercalary, and are oval to oblong and papillate at the apex. The great majority of the conidia are uniformly oval in shape, especially in liquid cultures. The measurements of the conidia from the liquid cultures were 47.6x54.9 (45.9-50x53.2-55.8)μ, while from agar cultures they were 31x41 (29.5-33.5x33-92.5)μ. The conidia germinate either by swarm-spores or by one to three or more germ tubes.

Chlamydospores were produced rather abundantly, especially in old cultures. They were globose and measured 24.7 (27.5-27.9)μ. Oospores were found in old cultures. These were thick-walled and globose and measured 21 (17.5-26)μ.

The above description agrees closely with that given by Sherbakoff for *P. terrestris*, and since the symptoms on the tomato were identical with those described by the same author for buckeye rot of tomato, the organism causing the disease in Indiana is in all probability that species.

Inoculations.—Inoculation work was done in the field late in the summer of 1921 with cultures of the Phytophthora isolated from tomatoes. Eighteen eggplant fruits were inoculated by making a very slight wound on the surface of the fruit with a flamed scalpel and placing very small pieces of mycelial growth from agar cultures on the wounds. Nine of the 18 inoculated fruits developed the rot, from which the same Phytophthora was later reisolated.

Thirteen pepper fruits were similarly inoculated and ten of the 13 inoculated fruits developed the rot. Six pepper fruits were inoclated by placing fragments of an agar culture on the unwounded surface and four of the six developed the disease. The fungus was reisolated from these infected fruits.

Inoculation of green tomato fruits in moist chambers in the laboratory, both with and without wounding the surface, by placing fragments of agar cultures on the surface of the fruits and over the wounds, produced a typical Phytophthora rot.

The inoculation of six small watermelon fruits by making a slight wound near the blossom-end and placing small blocks of agar cultures over the wounds gave negative results.

On Nov. 30, 1921, potatoes were surface sterilized, sliced with a flamed scalpel and placed in sterile moist chambers and inoculated by placing mycelium from an agar culture on the cut surface and incubated at 23°C. and 27°C. No infection occurred.

Temperature Relations.—A series of cultures was grown at different temperatures to determine the optimum temperature for the mycelial development of the organism. A very small block of an agar culture was planted in the center of each of a number of poured plates of potato agar. These plates were then placed in moist chambers and incubated at the following temperatures: 8°-9°, 12°, 15°, 20°, 23°, 27°, 30°, and 35°C. Measurements of the diameter of the colonies were made at different intervals. The measurements made at the end of nine days are given in table 1.

TABLE 1. Growth of *P. terrestris* at Different Temperatures.

8–9°C.	12°C.	15°C.	20°C.	23°C.	27°C.	30°C.	35°C.
No growth.....	20 mm.	30 mm.	32 mm.	35 mm.	35 mm.	50 mm.	32 mm.

From the above table it is evident that the optimum temperature for mycelial development is about 30°C. and that low temperatures are not favorable to its development. (These temperature relations are illustrated in figure 2, C.)

The fact that the organism attains its maximum development at a relatively high temperature in a humid atmosphere might explain the outbreak of Phytophthora in Indiana in 1921. The disease appeared at Lafayette during the first three days of August, 1921. The weather conditions at Lafayette, as given by the U. S. Weather Bureau at Indianapolis, show that for the last three days of July and the first three days of August the mean temperature was 77.5°F. The average maximum temperature for the six days was 86.5°F. which is equivalent to 30.2°C. The average minimum temperature for the six days was 68.5°F. or 20.2°C. The average maximum temperature was very favorable for the maximum development of the fungus, and the average minimum temperature was high enough to permit good growth of the organism. The record of precipitation for the last three days of July and the first three days of August show that on July 30, there was 1.06 inches of rainfall, on August 2, 2.20 inches, and on August 3, 0.85 of an inch, or a total of 4.11 inches for the six days. This is more than the average total rainfall for the entire month of July or August.

From the above data, it is quite evident that temperature and moisture conditions were ideal for the development of the fungus, especially the amount of soil moisture which is undoubtedly the most important of the two factors.

The records further show that the weather conditions for the months of August and September were conducive to the continued development of the disease. The average mean temperature for both months was above normal, and the total precipitation was about double that of the normal for these two months. In August it rained 0.01 of an inch or more on ten different days and 0.01 of an inch or more on twelve different days in September, supplying an abundance of soil moisture at all times.

As previously stated, tomatoes were grown on the same ground in 1922 and no buckeye rot developed. The importance of the soil moisture is again brought out when the records of the U. S. Weather Bureau are consulted. During the months of July, August, and September, 1922, the temperature at Lafayette averaged slightly above normal, but the rainfall for the same months was far below normal, being 0.61 of an inch below normal for July, 1.35 inches below normal for August, and 1.53 inches below normal for September. Thus it can be seen that the most important factor in the development of the disease was lacking in the summer of 1922.

SUMMARY.

A Phytophthora rot of tomato, eggplant and pepper fruits occurred in the field at Lafayette, Indiana, in the late summer of 1921.

The same fungus was repeatedly isolated from diseased fruits, and successful inoculations were secured on eggplant and pepper with the fungus isolated from tomato. Subsequent reisolations from inoculated fruits were made.

The symptoms of the disease on tomato resemble very closely buckeye rot of tomato as described by Sherbakoff, and the fungus agrees mor-

phologically with *Phytophthora terrestris* Sherb., the causal organism of buckeye rot.

Under field conditions, natural infection of immature, uninjured, green tomato fruits occurred.

The lesion on the eggplant fruit was characterized by a conspicuous light border. The fungus grows rapidly in the tissues and causes a browning of the vascular elements and a premature dropping of the infected fruit from the pedicel. Infected peppers also dropped prematurely.

It is possible that the fungus causing the disease may be carried from one locality to another in the soil on the roots of young transplants.

The fungus attains its maximum development at about 30°C. in a humid atmosphere.

The weather records show that the temperature and moisture conditions at Lafayette during the week that the disease first appeared were very favorable for the development of the fungus and that conditions continued to be favorable for the development and spread of the disease.

Tomatoes grown on the same soil in 1922 showed no buckeye rot, probably due to the lack of soil moisture.

DIFFERENCES IN THE SUSCEPTIBILITY OF CLOVER TO POWDERY MILDEW.[1]

E. B. MAINS, Purdue Agricultural Experiment Station.

The powdery mildew of clover has aroused considerable interest this year (1922), because it has been widespread and abundant. This disease has heretofore been rare in America and in consequence the general whitening of clover by mycelium and spores of this fungus has caused more or less alarm among the farmers, from whom numerous inquiries have been received. The disease made its first noticeable appearance in the fall of 1921, and during the spring and summer of 1922 spread rapidly. According to the Plant Disease Survey[2], the mildew first made its appearance upon the first crop of clover in the South, and was first reported from Louisiana, April 10. With the advance of the season, it spread northward and by June 28 was reported in Maine and Minnesota. The writer saw the disease more or less prevalent practically everywhere on his trips through South Carolina, Virginia, Tennessee, Kentucky, Indiana, Wisconsin, and Michigan during May, June, and July. According to the Plant Disease Survey[3], the first record of this disease in the United States was from Prof. Sheldon who reported its inconspicuous occurrence in the vicinity of Morgantown, W. Va., in 1908. In 1915, reports were received from Idaho, Washington, and Oregon, and in 1916 and 1917 from Utah.

There is some question as to the identity of this mildew, since, as far as the writer is aware, no perithecia have been found accompanying the disease, at least in the eastern United States. Miss V. K. Charles (*l.c.* 3) found perithecia on collections from Oregon, Washington, Montana, Colorado, and Idaho, but not from any of the eastern states. Since all clover mildew has been considered as belonging to the species, *Erysiphe Polygoni* D.C., it is very likely that the mildew so prevalent in the eastern United States is this species and that the proper conditions for perithecia formation have not occurred in this region.

Although it is generally agreed that clover mildew has been very severe, there seems to be considerable difference of opinion among pathologists as to the damage caused (*l.c.* 2, 3), some believing very little damage is caused while others believe considerable loss is suffered. The reasons given for attributing loss to this disease, are the death of the lower leaves (Fromme) causing hay to be slightly off color and of poorer quality, the reduction in tonnage by death of lower leaves and also the proportionally higher percentage of stems (Edgerton), and the greater shattering and powdering of the leaves in hay from diseased fields (Elliot). This is one of the diseases of plants for which it is hard to obtain any accurate estimate since it does not kill the plants attacked nor reduce the yield to such a marked extent but that the loss

[1] Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

[2] U. S. Dept. Agr. Plant Disease Survey Bull. Vol. 6, No. 1, pp. 8-14. 1922.

[3] U. S. Dept. Agr. Plant Disease Survey Bull. Vol. 6, No. 3, pp. 53-55. 1922.

can be attributed to weather conditions. However, it hardly seems possible that fields can be so thoroughly infected with a disease that they "look as if they had been heavily dusted with flour" (Edgerton) and "when the mower goes through the field a white cloud arises on all sides" (Anderson) without the fungus interfering considerably with development and yield of its host. Not only must considerable food be withdrawn from the host by the parasite but also the mat of mycelium on the surface of the leaves and the haustoria within the cells must interfere considerably with photosynthetic activities of the plant and thus prevent, to a more or less extent, the manufacture of the plant's food. The withdrawal of food and the weakening of the plant undoubtedly brings about the premature death of parts of the plant such as the older, longest-infected leaves but not so rapidly but what new leaves take their place, which in turn gradually are infected. However, the plant as a whole is probably very seldom if ever weakened so much as to succumb entirely except after prolonged attack. In the absence of destruction or serious weakening of all or part of the crop, there is no good basis for measuring loss since the widespread occurrence of the disease precludes the opportunity of comparing diseased and disease-free fields of like fertility, and otherwise comparable. As indicated above, the enormous mycelial and spore production must reduce to some extent the stored food of the clover plant and correspondingly its feeding value. The premature death of the older leaves and possible increased shattering of the diseased younger leaves is another source of loss. If the second crop of clover is saved for seed, possibly the loss may be more easily measurable since with the lowered food content of the clover plant there is likely to be a reduction in the number or quality of seed matured.

A matter of considerable concern to the farmers is whether mildewed clover is fit for feed. From the evidence furnished by the Plant Disease Survey (*l.c.* 2) no harm is liable to result from feeding such clover. Hesler reports that tests conducted by the Tennessee Experiment Station indicate that stock (horses, cattle, sheep, swine) is not injured after being fed or grazed 14 days on mildewed clover. Edgerton reports that no poison or injurious substance is formed. Dungan quotes C. M. McWilliams, Farm Adviser of Randolph County, Illinois, who observed no ill effects from feeding the mildewed clover to cattle, horses, and mules. There is a possible slight danger in feeding the hay to horses on account of the presence of the spore-dust. Tehon reports a trouble in cattle similar to 'heaves' attributed to mildewed clover in southern Illinois.

Control of a disease of the nature of mildew under the cultural conditions necessary for clover is extremely difficult, and apparently the only feasible method is in the discovery or development of disease-resistant strains. The biology of the mildew of clover, however, has not been extensively studied. Salmon[4], upon a morphological basis, considers the mildew of clovers as *Erysiphe Polygoni* DC. for which he gives 359

[4] Salmon, Ernst S. A Monograph of the Erysiphaceae. Mem. Torrey Bot. Club. 9:1-292. 1900.

species belonging to 154 genera as hosts. He gives the following species of clover as hosts: *Trifolium agrarium, T. alpestre, T. arvense, T. filiforme, T. hybridum, T. incarnatum, T. involucratum, T. longipes, T. lupinaster, T. medium, T. minus, T. monanthum, T. montanum, T. moranthum, T. pauciflorum, T. pratense, T. procumbens, T. repens*, and *T. rubens*. That *E. Polygoni* must consist of a large number of specialized races is indicated by the researches of Neger and Salmon[5], the former being unable to infect *Trifolium repens, Vicia sepium* or *Hypericum montanum* with conidia from *T. incarnatum*, and the latter finding that the mildew from *T. pratense* would not infect *T. agririum, T. repens, T. medium, T. montanum, T. incarnatum, T. filiforme, Lotus corniculatus, Melilotus arvensis, Medicago sativa, Lupinus lutens* or *Pisum sativum*, but infected *T. pratense* heavily. According to this, the mildew on *T. pratense* is a race restricted to that species of clover. Likewise the mildew on *T. incarnatum* represents another closely restricted race. Observations by various pathologists during the past year as reported in the Plant Disease Survey agree with these results.

There are evidently few or no observations upon varietal or individual differences in the reaction of *T. pratense* to the specialized race of mildew which exists on it. Dr. A. J. Pieters (*l.c.* 2) has observed at Arlington, Virginia, that many of the American varieties of red clover were affected while most of the European strains were free or nearly so. In the fall of 1921, the writer noticed that considerable differences existed between the species of Trifolium as to susceptibility to mildew, and also that similar differences were to be found between varieties of *T. pratense*. The plants upon which these observations were made were started in pots of sterilized soil in the greenhouse and were transplanted to the field in late summer. The plants were set about ten inches apart in rows two feet apart, so that there was no difficulty in observing individual differences. By October 13, when notes were taken, the plants were well established and in good condition. The notes given in the following table represent the reaction of individuals and varieties under field conditions to natural infection of the powdery mildew.

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[5] Salmon, Ernst S. On Specialization of Parasitism in the Erysiphaceae. Beihefte Bot. Centralbl. 14:261-315. 1903.

TABLE I. Susceptibility of Clovers to Powdery Mildew in the Field, Lafayette, Ind., October 13, 1921.

Species and Variety	Original Source of Seed	No. of Plants Examined	Degree of Susceptibility—No. Plants			
			Heavy	Moderate	Slight	None
Trifolium pratense 2019*	South Dakota	44	13	22	9	....
Trifolium pratense 2020	Ohio	44	9	15	19	1
Trifolium pratense 1809	North Dakota	9	2	....	7	....
Trifolium pratense 2055	Chile	17	....	1	16	....
Trifolium pratense 1819	Italy	10	....	....	8	2
Trifolium pratense	France	44	....	....	15	29
Trifolium pratense 43592	England	10	....	....	....	10
Trifolium incarnatum 2054	....	10	....	....	....	10
Trifolium hybridum 2047	....	12	....	....	....	12
Trifolium repens 48625	Holland	8	....	....	....	8
Trifolium repens 1928	Wisconsin	10	....	....	....	10
Trifolium repens 1912	Idaho	25	....	....	....	25
Trifolium repens 48019	England	12	....	....	....	12
Trifolium subterraneanum 51212	....	10	....	....	....	10
Trifolium fragiferum 29012	....	12	....	....	....	12
Trifolium reflexum 03308	....	12	....	....	....	12

*Numbers following names are those used by the Office of Forage Crop Investigations, U. S. Dept. Agriculture.

Encouraged by these results, further work was started this past summer (1922). Seed of 17 varieties of clover grown on the Experiment Station farm at Lafayette, Indiana, were sown in individual flats of sterilized soil in the greenhouse. About midsummer the mildew showed up and spread fairly rapidly. In order that all the flats might be uniformly inoculated, they were dusted with the mildew the latter part of November, atomized and kept covered with moist cloths for several days. The mildew developed rapidly and by the first of December the older leaves of a number of the varieties were white with the mycelium and spores. The plants were then taken from the flats, sorted according to susceptibility, counted and the immune and highly resistant plants were transplanted. The varieties tested and the results obtained are given in table II.

TABLE II. Susceptibility of Varieties of Red Clover, *Trifolium pratense* to Mildew, in Greenhouse Tests, December 1, 1922.

Varietal No.	Original Source of Seed	No. of Plants Examined	Degree of Susceptibility, No. Plants		
			Heavy	Moderate—Slight	None
2135	Ohio	206	151	39	16
2138	Tennessee	133	90	30	13
2148	Oregon	117	45	55	17
2203	Chile	113	12	88	13
2217	Chile	129	43	68	18
2142	Chile	130	25	73	32
2055	Chile	138	28	67	43
2218	North Germany	230	34	129	67
2214	Hamburg	128	7	55	66
2121	Bohemia	221	1	109	111
2219	Hungary	215	7	147	61
2202	France	127	6	87	34
54456	France	140	15	73	52
54493	France	127	10	76	41
54492	Italy	153	9	95	49
54779	Italy	139	....	68	71
2212	Italy	168	3	95	70

An examination of table I shows that, among the various species of Trifolium represented, only *T. pratense* was mildewed. *T. incarnatum*, *T. hybridum*, and *A. repens*, all of which are given as hosts for *Erysiphe*

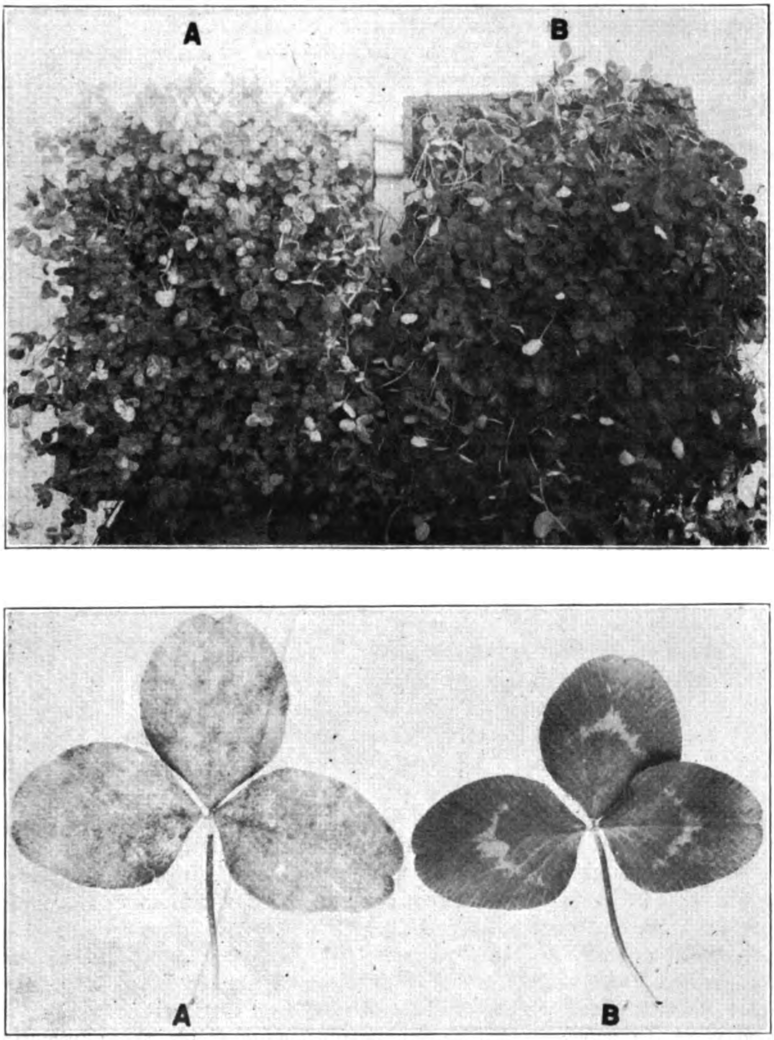

Fig. I. Difference in Susceptibility to Mildew. (A and B.) Difference in Two Clover Varieties. A. Flat of Tennessee 2138 clover susceptible to mildew. B. Flat of Italian 54779 clover resistant to mildew. (A′ and B′.) Difference in Two Plants of Variety Ohio 2185. A′. Leaf of susceptible plant. B′. Leaf of immune plant.

Polygoni, were absolutely free from mildew. This, therefore, would agree with the results of Salmon as well as the observations of a number of pathologists in this country in 1922 that the mildew of red clover

is restricted to that species. However, not all of the varieties of *T. pratense* were found to be susceptible. An examination of tables I and II shows an interesting situation, the North American varieties being generally quite susceptible, while the European show in general rather high resistance. The Chilean seemed intermediate between the two. Figure I (A and B) shows the difference in susceptibility shown by a flat of the variety Tennessee 2138 and a flat of the variety Italian 54779.

What the significance of this situation may be, is hard to say. It is possible that the long presence of mildew in Europe may have had a selective effect, possibly preventing the formation of seed in susceptible plants. This would necessitate a very marked effect of the mildew on seed production. On the other hand, the absence of mildew in this country would preclude any such selection. However, as far as the writer has been able to determine, no one has noted red clover resistant or immune to mildew in Europe. On the other hand, judging from the lack of comment on the disease, it may not be serious at the present time, possibly indicating resistance but not complete immunity. It is useless, however, to theorize until we have a better knowledge concerning the biology of this disease and the relation of the race on *T. pratense* to a greater number of other species of Trifolium, especially native wild species, and until we know whether differences exist between the mildew in North America and Europe in its ability to attack varieties, whether the mildew in this country has been recently introduced or whether climatic conditions of the past year have been responsible for the development and conspicuous appearance of the disease, and what the effect is on the clover plant, especially upon seed production.

Another thing noticeable in tables I and II is the presence of resistant individuals in all except three of the varieties tested. It is likely that if a larger number of plants of these three had been tested, resistant plants would also have been found among them. Figure I (A′ and B′) shows a leaf from a susceptible and a leaf from a resistant plant of Ohio 2135.

As we have already noted the discovery or development of resistant varieties suggests the most likely control. Unfortunately in most cases the presence of one or more undesirable qualities in resistant varieties complicates the situation. Thus several of the resistant European varieties apparently are not especially adapted to our climate, since those in the field during the comparatively mild winter of 1921-1922 winter killed badly. Prof. A. T. Wiancko[6] has stated that in his field tests of clover varieties, the Italian killed out entirely during the winter of 1920-1921. In consequence it appears very doubtful if these varieties would be of much value except for hybridizing work. Unless other European varieties prove to be hardy, the most promising method of obtaining mildew-resistant strains appears to be by the selection of resistant individuals in American varieties.

[6] Wiancko, A. T. Report of the Director, Purdue University Agricultural Experiment Station. 1921:37.

TABLE III. Source of Seed and Its Bearing on Winter Injury.

Condition of Varieties of *Trifolium pratense*, Spring, 1922

Varietal No.	Original Source of Seed	Condition—No. of Plants Good	Poor	Dead
2019	South Dakota	30	6	8
2020	Ohio	33	4	7
1809	North Dakota	7	1	1
2055	Chile	3	7	7
1819	Italy	....	1	9
....	France	3	11	30
43592	England	....	1	9

SUMMARY.

1. The mildew of red clover, *Trifolium pratense*, is apparently specialized on that host, crimson, *T. incarnatum*, Alsike, *T. hybridum*, and white, *T. repens* not being infected.
2. Considerable differences exist between varieties of red clover as to susceptibility to the mildew, American varieties being much more susceptible than European.
3. Resistant individuals are probably to be found in all varieties, the number varying with the variety.
4. Selection and breeding for resistance offers the best means for controlling the disease.

The writer wishes to acknowledge his indebtedness to Dr. A. J. Pieters, Office of Forage Crop Investigations, U.S. Dept. of Agriculture, and Mr. R. R. Mulvey, Soils and Crops Dept., Purdue Agricultural Experiment Station, for furnishing the seed of clover varieties upon which this work was done.

THE PRESENT STATUS OF THE HOT WATER TREATMENT IN INDIANA.[1]

C. T. Gregory, Purdue University Agricultural Experiment Station.

The first application on the farm of the hot water treatment of wheat for the control of loose smut was made in Indiana in 1917 by six men in five counties. Since that time the number has steadily increased until in 1921 there were about 850 farmers in 50 counties who treated their wheat. Moreover, the influence of the treatment has been spread by the ever increasing supply of seed from treated fields. For example, in Shelby County, where some of the pioneer work was done, there is a supply of 25,000 bushels of such seed this year (1922); Hancock County has over 2,000 bushels; Gibson County, 3,000 bushels; Posey County, 5,000 bushels; and Wayne County, 4,900 bushels. It is reported that there are 29,000 acres in Knox County planted with seed from treated fields.

As is usual when a laboratory control method is first applied on the farm many unforeseen changes were necessary to make the method entirely practical. The particular changes that have been made can best be discussed under the different phases of the treatment.

1. *Presoaking.* It has been proven that presoaking is one of the essential steps in the treatment. The early recommendation, to soak the wheat in cold water for eight hours, is perfectly proper but under farm conditions this time is too long because the treating usually begins about 9 A.M. making it necessary to begin soaking the seed at 1 A.M. Investigations showed that four hours presoaking was sufficient and that 12 hours soaking is dangerous because the seed is quite apt to germinate and thus be rendered much more susceptible to injury by the treatment to follow. A peculiar mistake in the presoaking recommendations was made in Porter County last year. The farmers thought that any four hours previous to treatment would do and they soaked the wheat during the previous afternoon. Promptly at the end of the time they removed the sacks from the water but allowed the soaked wheat to stay in the sacks until the following morning thus permitting sufficient germination to prevent successful treatment.

Not more than one bushel of dry wheat should be soaked in a two bushel burlap sack because it swells to almost twice its original bulk. If the sacks are too full the seed will soon become packed and either burst the sacks or, as sometimes occurs, the tight outer layer excludes the water and the wheat in the center is not properly soaked. Because of this propensity of the seed to swell and tightly pack, the sack should be laid on its side in the water, rather than on end.

2. *The Treatment.* At first a half bushel of wheat was treated in a barrel of hot water, the temperature being maintained by adding boiling water from time to time. In Shelby County where large amounts of wheat were treated this method was too slow and a rather ingenious

[1] Contribution from the Department of Botany (Extension Division) of the Purdue University Agricultural Experiment Station.

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device was made to meet the emergency. It consisted of a heavy wire drum holding five bushels of soaked wheat, which revolved in a large tank of water heated by steam. This is distinctly a field application of the treatment. However, the sack method is still frequently employed, but instead of barrels, large tanks of water heated by steam are used so that six to eight men may treat their wheat at one time.

A device which enables the operator to keep the wheat in the hot water without burning his hands consists of loops of heavy twine fastened by a slip-noose to the mouth and one corner of the sack. It has been noted that grain sacks are unsatisfactory for treating because the tightly woven cloth seems to prevent the ready passage of the water through the wheat, and burlap sacks are therefore recommended. When using the drum not more than five bushels of wheat should be treated at once and the drum should not be filled more than two-thirds full. This allows a free movement of the wheat and a quick and thorough mixing with the hot water.

The time of treating and temperature of the water have not undergone any change. Temperatures as high as 135°F. will not injure wheat, and it is also known that immersion in water at 130°F. for 15 minutes will not do any particular harm to the seed. However, these facts are only used as leeway in the treatment rather than as changes because it is necessary to speed up the treatment as much as possible and there is usually nothing to be gained in lengthening the time of treatment.

3. *Drying the seed after treatment.* Perhaps the greatest drawback to the treatment is the drying of the seed. It has been found, however, that it is only necessary to surface-dry the grain so that it will run through the drill without clogging. Allowance is made for the swollen condition of the grain by setting the drill to sow about twice as much as customary. Experiments at Washington, D.C., have shown that wheat can be dried very thoroughly in artificial dryers without injury to seed. One illuminating incident happened this year in Clinton County. Some treated wheat remained wet too long after treatment and produced sprouts that were in some cases a quarter of an inch long. A sample of this seed was dried completely over a radiator and sent to Purdue to be tested. It germinated 92.5 per cent.

Results. Usually the stand of the treated wheat is thin but the plants stool much more than the untreated wheat so that the final number of heads produced is about the same in both cases. It has been noticed generally that the heads in the treated wheat are much more uniform in size and are usually somewhat larger than in the untreated. It is possible that the thinning of the stand may have something to do with this but it is believed that the treatment kills the weak seed and that only the stronger plants survive. This belief is supported by the fact that the improvement in the crop usually maintains itself in the wheat the second and third year after treatment.

The treated wheat will usually ripen about a week later than the untreated wheat, but this is not an objectionable feature. This delay in ripening did, however, result rather disastrously in Bartholomew County two years ago. The weather was apparently unfavorable during

the time of filling and ripening and since it had a week more to act on the treated wheat the grain was considerably shrivelled and really inferior to the untreated wheat. The farmers blamed the treatment for the trouble.

It was noticed at first that certain weeds like cockle and rye would often be killed by the treatment. This led to rather false hopes for the treatment and some county agents went so far as to recommend the hot water treatment as a means of ridding the wheat of cockle. We have found, however, that this cannot always be depended upon. In Posey County it has been found that a treatment of 15 minutes at 130°F. is more effective in killing cockle and that it will not materially injure the wheat more than the ten minute treatment. Experiments in treating cockle seed have shown that one controlling factor is the length of time that it is presoaked. With the cockle seed used, it was found that after 12 to 24 hours of soaking the germination was reduced very materially by the treatment. It seems, too, that fresh cockle seed is more susceptible to injury than old seed.

Without question the treatment will control the loose smut but there are certain factors which have been found to prevent a perfect control. These are: 1. Insufficient presoaking of the seed; 2. Imperfect heating of the seed due to excessive amounts of wheat in the sack or the drum; 3. An incorrect thermometer, registering too high so that the actual temperature of the water was below 129°F. The stinking smut, however, is not always controlled. This is apparently due to the inability of the heat to kill the spores in the center of the smut-filled seed, followed by the subsequent breaking of these spore masses, which results in the distribution of viable spores over the wheat. In Porter County in 1922 there was one field where the treated wheat had 10 per cent of stinking smut and the untreated part about 12 per cent.

Changes made in the field applications. The original recommendation for eradication of loose smut, given by Freeman and Johnson in bulletin 152 of the Bureau of Plant Industry, and at first followed in Indiana, was as follows: Treat enough wheat for a small seed plot, about five bushels, and select the seed for the next year's crop from this plot. The first objection to this program came from the farmer. He could not or would not keep this small area separate from the rest of the wheat. Usually it was necessary to plant this patch in a larger field and when it came to cutting this separately and hauling it to the threshing machine separately the trouble began. The farmers who had been convinced of the value of the treatment treated enough seed for a whole field and supplies of supposedly smut-free wheat began to appear. With the advent of wheat certification, which calls for practically smut-free wheat, the treatment became more popular. It soon became evident, however, that using wheat from a smut-free field did not guarantee a smut-free crop owing to the fact that the spores could easily be blown from neighboring or even distant fields. This showed the fallacy of recommending the seed plot method or even separate fields of treated wheat and also seems to be one of the factors which has been retarding the spread of the practice. The farmers feel that it is useless to treat

a small amount of seed if the wheat produced is liable to give a badly diseased crop the next year.

Another old idea which has acted against a wider application of the treatment has been that the farmers themselves can not handle the treating because it is too complicated and dangerous. The whole treating project is being revised this year. It has been demonstrated in Knox and Shelby counties that a widespread use of treated seed will greatly reduce the dangers of the spread of the smut. In Knox County it was found last summer that wheat which had been treated last year had no smut in it; that which was one year from treatment had no smut; two years from treatment there was one-quarter per cent; and three years from treatment two per cent while in the untreated fields there was an average of eight per cent. This shows rather clearly that the best way to handle this problem is to establish smut-free areas or communities. In order to do this it is evident that the actual treating in a large area would soon become too great for one station to handle. This was solved by placing the treating stations in the hands of the farmers themselves. Five groups of farmers in Clinton County, three groups in Marion County and one group each in Henry and Wabash counties treated a total of over 800 bushels. In every case enough seed was treated to plant a whole field and so far as the treatment itself was concerned the work of these farmers was a complete success.

The steps in advance that have been made are these:

1. Enough seed is being treated for whole fields so that it will be much easier to keep this wheat separate and propagate the seed.

2. The farmers themselves are beginning to handle the treatment and in this way greatly increasing the number of centers from which the treated wheat can start.

3. Smut-free areas are being established in which it is hoped that wheat can be maintained free from loose smut for several years.

ONION SMUT IN INDIANA.[1]

C. T. GREGORY, Purdue University Agricultural Experiment Station.

A survey of all the important onion growing regions of Indiana in 1922 showed the smut disease to occur abundantly in Lake County, around Munster, and in one locality near Rensselaer in Jasper County. In the vicinity of Munster there is a considerable industry in the growing of onion sets and in these fields the disease is very severe, frequently causing losses of 50 per cent or more. The losses caused are of two types, a direct loss by the destruction of the plants and indirectly by the production of over-sized onions which are often discarded as they are not salable as sets. These over-sized onions are the result of a thinning of the stands by the disease permitting the onions that remain to grow more than is desired. In addition, it has been found that the

[1] Contribution from the Botanical Department (Extension Division) of Purdue University Experiment Station.

shrinkage in storage of the onions grown in infested fields is very much greater than in those from uninfested fields or from formaldehyde treated seed.

It has been proven beyond a doubt that the formaldehyde "drip" method of treatment will control the onion smut very effectively but the method was designed to apply to onions that are sown at the rate of five to seven pounds per acre. In Lake County, where the seed is sown at the rate of about 60 pounds per acre, the problem is somewhat different. Under these conditions the control is never 100 per cent but it has been sufficiently effective to secure its adoption by the majority of growers. The probable explanation of the control by the formaldehyde treatment is that the gas evolved disinfects the soil in the immediate vicinity of the seed through which the seedlings must grow thus killing the spores or the saprophytic mycelium. This disinfecting action does not seem to extend over a sufficient area to permit the large number of seedlings developed in the row to grow in disinfected soil and as a result a small proportion of the plants may be diseased. This may possibly be explained by the fact that the formaldehyde does not wet an area more than three-quarters of an inch wide, though the gas may spread somewhat beyond this, whereas the row of onion seedlings is about an inch and a quarter wide.

Aside from the failure of the formaldehyde to completely disinfect the soil there are other factors that seem to affect the efficiency of the treatment. The growers believe that spring plowing so loosens the soil that the formaldehyde penetrates too deeply for proper or sufficient disinfection. The amount of rain at planting time and immediately following is very important. In 1921 the heavy continuous rains at the time of treatment, and during the week following, practically nullified all the beneficial effects. The probable explanation of this fact is that the rain diluted the disinfectant so that it lost its potency, or else the presence of the water in the soil prevented uniform penetration.

The usual recommendation for dilution is one pint of 40 per cent formaldehyde in 16 gallons of water, to be used at the rate of 200 gallons per acre.

The treated onions had about five per cent of smut while the untreated parts of the beds averaged about 50 per cent. Increases in yields of 100 bushels per acre were obtained.

The growers at Munster found that they were usually applying only 140 to 160 gallons so it was decided to dilute the formaldehyde, one pint in 10, 12, and 14 gallons of water. This was done in 1922 with somewhat better control of the smut and without causing any injury to the seedlings. Rather peculiar results were obtained, however, from the treatment. The soil at the time of sowing was dry and the weather very favorable for the treatment. An examination of the fields in June showed the treated rows had less than five per cent of smut while the untreated rows had as much as 95 per cent in some cases. In one field where the grower did not use the treatment, over half of the plants were being destroyed by the smut. During the summer there were no effective rains and the temperature was generally above normal. These

abnormal conditions had a particularly harmful effect in the treated rows while the untreated rows were apparently not so seriously affected. The results of some of the growers are as follows: Joe Munster, who treated all his seed, reports that he did not harvest the crop because it was a complete failure. John DeVries did not get any difference in yield between his treated and untreated fields. Andrew Krooswyk states that his treated seed was somewhat better than the untreated but neither was worth much. In other words, the treatment did not seem to have had the beneficial effects obtained in previous years.

The explanation of this trouble seems to be that the treatment permitted a heavy growth of onions whereas the untreated areas were very much thinned by the smut. The continued dry weather so depleted the soil of water that in the heavy, normal stands the plants were unable to make any growth and as a result most of the bulbs did not develop. On the other hand, there was not so much competition among the plants of the diseased (untreated) rows and the few that remained were able to get sufficient moisture to develop small bulbs which were just the right size for sets. This resulted in approximately the same yields in the treated and untreated onions. Viewed in connection with previous experiences and from all angles, this peculiar and unexpected effect is really an argument for the treatment since it shows that smut control permits a much thicker stand which in normal years would produce an almost perfect yield.

THE MAKING OF GENERA IN FUNGI.

J. M. VAN HOOK, Indiana University.

The question of genus making and what it takes to constitute a genus, has provoked much discussion from the earliest times and we are now possibly no nearer its solution than before, possibly farther away.

The object of this brief paper is to present one point of view and one which is very apparent even to the youngest student of systematic mycology. It occurs to the student that genera are often erected for convenience and for the convenience of analytic keys rather than for any great scientific differences in their characteristics. He often finds genera widely separated in sequence in texts, when in reality they may possess only a single slight difference and this difference may not be constant among the various species of the genera. As an illustration of the above, we may cite the case of Pleurotus and Claudopus among the Agaricaceae. The chief difference between these two genera seems to be that of spore color. This single difference, and we have many such genera, necessitates a separate genus because of a major division of the family based upon spore color. The specimen at hand whether it be a Pleurotus or a Claudopus, may be traced through the key to exactly the same place except as to spore color. When, however, one tries to classify such a well recognized species as *Pleurotus sapidus* Kalchbr., he will likely refer it to the genus Claudopus on account of the beautiful light grayish vinaceous spores in mass. These so-called pink spores will retain their color for many months in a strong light. However, after a study of the very similar oyster agaric, *Pleurotus ostreatus* Fr., one can scarcely make a separate species out of *P. sapidus*, much less a genus. Certainly it belongs to the pink-spored group as far as spores are concerned, although no one of experience would consider it a Claudopus.

In the group of Ascomycetes, we find the genus Rosellinia widely separated from Hypoxylon by certain mycologists on account of the separate perithecia of the former and the stromatic perithecia of the latter. Yet even a superficial study of the family Xylariaceae will display Rosellinia forms whose perithecia coalesce and Hypoxylon forms whose perithecia are separate. Where such forms occur, we have Rosellinias that are apparently Hypoxylons and Hypoxylons that are apparently Rosellinias. If broader and better characters had been chosen on which to base the above genera, this confusion would not occur and these closely related genera would not be placed in widely separated families. In view of the remarkable similarity of the species of these genera, as to habitat, external appearance and spores, we see scarcely more than a subgeneric difference at the most. Saccardo seems to be one who did not fall into the usual error and used a system based upon spore-color which happens to place Rosellinia where it rightfully belongs.

In this same family (Xylariaceae), we notice the closely related genera, Nummularia, Hypoxylon and Daldinia. The globose forms of

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all three are almost identical and have similar spores. While one of the chief generic characteristics of Daldinia is the concentric layers of its stroma, we have a rather common species of Hypoxylon whose most noticeable characteristic is that of concentric stromatic layers. It follows that a student learns these similar fungi as individuals rather than by following a key to genera and species. Concerning Nummularia, Ellis and Everhart say: "The genus is too closely allied to Hypoxylon, especially the discoid forms."

Among the imperfect fungi, a group in which the writer is particularly interested, genera seem to have been formed for convenience in many cases and we have been led into species multiplicity and countless errors.

As an example, we cite the common genera, Phyllosticta, Phoma and Macrophoma. When the first two were set apart, their only difference was that of habitat. If on a leaf, it was Phyllosticta; if on any other part of a plant, it was a Phoma. When one considers the similarity of a young shoot and a leaf, he wonders why such a division was ever made. Furthermore, those species of the genus Phoma having spores more than fifteen microns long, were placed in a separate genus, Macrophoma, this arbitrary difference in spore length sufficing for a new genus.

The entire group of imperfect fungi abounds in similar examples. In the Hyphomycetes, the group with scattered and tufted conidiophores is separated into the families Mucedinaceae and Dematiaceae entirely on the basis of mycelium color, yet this basis was not used in separating the Stilbaceae and Tuberculariaceae.

It is to be noted also that genera have been based upon spore shape. In the classification group known as Scolecosporae, a spore must be long in proportion to its width. But just what proportion? While a standard of proportion may be attained by long study of the groups, the actual determination, left to the individual, has resulted in the placing of those fungi with spores of intermediate proportion in the group which suits the judgment of the individual. As a result, a student must search through several genera to locate his plant. A spore size limit as in the case of Phoma and Macrophoma would be preferable.

The common practice of forming sub-groups of any kind for the purpose of classification where the groups are large and unwieldy, has in many cases, resulted in the establishing of many doubtful or peculiar genera.

NOTES ON MICROTECHNIQUE II.

M. S. MARKLE, Earlham College.

The damage done to recently mounted microscopic slides by a class of freshmen is well known; yet is it often impossible to anticipate one's needs sufficiently to allow time for slides to harden. This is especially true of slides mounted in Venetian turpentine, which hardens more slowly than balsam. I have found that slides may be used at once, after being mounted according to the following method.

The Venetian turpentine into which the material is finally brought is allowed to dry until it is quite hard—so thick that its surface may be indented with difficulty. This is softened by being placed on a warming-plate. The material when sufficiently warmed to be thin enough for ready mounting is placed on the slide on another hot-plate, the material is arranged with needles, a cover is added and the material allowed to fill the space under the cover.

With a little more care, stem sections, and even paraffin sections may be mounted in balsam in the same manner. I have been much surprised to find what extreme temperatures sections will endure without damage. By accident, some slides of *Marchantia* antheridia were mounted and left on a hot-plate 22 hours. I supposed they would be ruined, but careful examination showed no damage. A thermometer placed on the hot-plate showed a temperature of 145° C.

A convenient hot-plate for such work or for stretching paraffin ribbons or for warming imbedding-dishes while the pieces of material are being arranged may be made by mounting an ordinary electric bulb inside a box over which a piece of glass has been placed. A discarded photographic negative is satisfactory. For higher temperatures, a piece of zinc or sheet brass is better. Temperatures may be modified by varying the wattage of the electric bulb used. Very high temperatures may be gotten by mounting the bulb vertically and placing over it a tin cylinder covered with asbestos paper. A thin lantern slide plate was used for several weeks over the hot-plate mentioned above as giving a temperature of 145° C. without breakage.

I have been using with great satisfaction the gelutin-glycerin fixative described in the Botanical Gazette, April, 1919, by Artschwager. I use phenol instead of sodium salicylate. The results are superior to those obtained by the use of egg albumen.

Even with the best of fixatives, some materials persist in coming off the slide during the staining-process, especially when aqueous stains, such as the haematoxylins, are used. Following a suggestion by Dr. F. D. Lambert, of Tufts College, I have used with excellent results the following method. After the paraffin has been dissolved in xylol and the xylol has been removed with alcohol, the slides are dipped in a very weak solution of celloidin in alcohol and ether. The slides are removed, allowed to drain but not to dry and are carried through the staining-process in the usual way. Celloidin stains heavily in haematoxylin, but by the time the destaining is completed, no trace of the stain remains in

the celloidin. In this way I have saved thousands of slides that would otherwise have been lost. Small structures, such as spores, starch-grains, and the like, are readily retained in the sections.

Recently in mounting some epidermis of tulip for the study of stomata, I noticed that many of the nuclei of the epidermal cells were dividing amitotically. Many stages could be observed in a single field of view. I do not know how commonly this may be found in tulip epidermis, but the material described is the best I have seen for the demonstration of amitasis.

CONSTITUTION AND BY-LAWS

INDIANA STATE ACADEMY OF SCIENCE.

CONSTITUTION.

ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SEC. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other sources and riches of the State; to arrange and prepare for publication such reports of investigation and discussion as may further the aims and objects of the Academy as set forth in these articles.

WHEREAS, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident members, and active members.

SEC. 2. Any person engaged in any department of scientific work, or in any original research in any department of science, shall be eligible to active membership. Active members may be annual, life members or patrons. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars and thereafter an annual fee of one dollar. Any person who shall at one time contribute fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Any person who shall at one time contribute one hundred dollars to the funds of this academy may be elected patron, who shall be a life member of the Academy, free of dues. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Application for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SEC. 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

ARTICLE III.

SECTION 1. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary, Editor, and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SEC. 2. The annual meeting of the Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past President, together with the officers and Executive Committee, shall constitute the council of the Academy, and represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

SEC. 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.

2. The President shall deliver a public address on the morning of one of the days of the meeting at the expiration of his term of office.

3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.

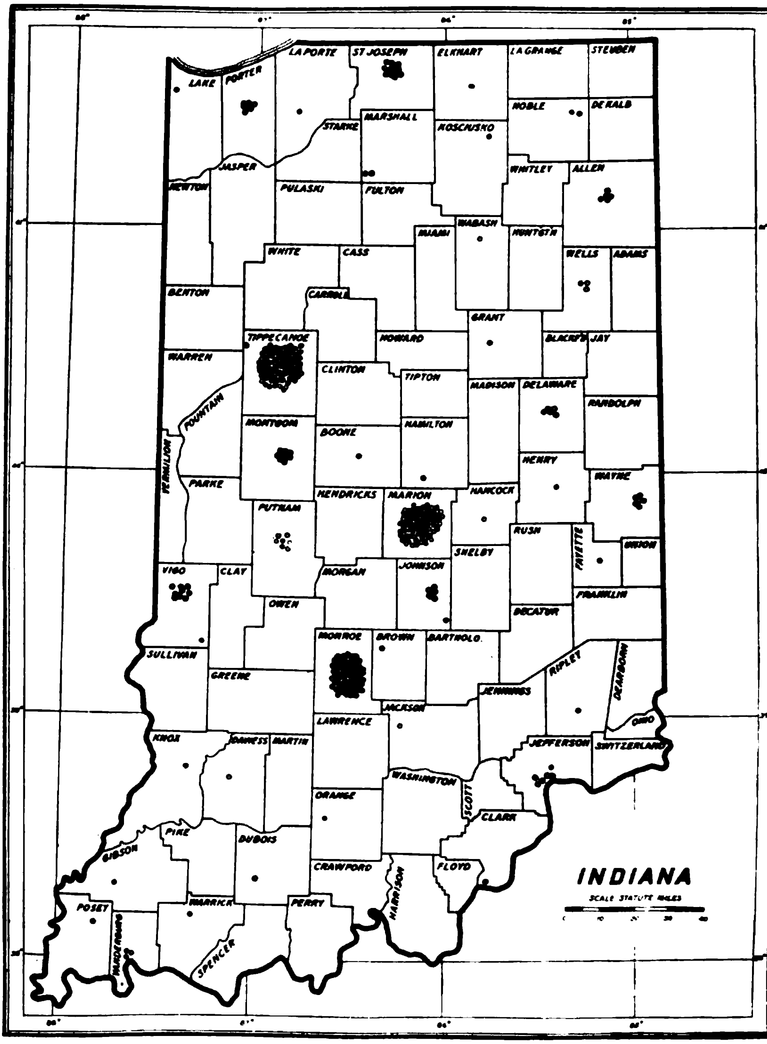
4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.

5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.

6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

7. Ten members shall constitute a quorum for the transaction of business.

8. An Editor shall be elected from year to year. His duties shall be to edit the annual Proceedings. No allowance shall be made to the Editor for clerical assistance on account of any one edition of the Proceedings in excess of fifty ($50) dollars, except by special action of the Executive Committee.



Geographic Distribution of Members. Marion County, 9 fellows and 74 active; Tippecanoe, 11 fellows and 66 active; Monroe, 18 fellows and 39 active. Thirty-nine of the 92 counties are represented and 22 of the 39 have only one member.

MEMBERS.[1]

FELLOWS.

Andrews, F. M., 110 E. Tenth St., Bloomington	1896[2]	1911[3]
Arthur, Joseph C., 915 Columbia St., Lafayette	Charter	1893
Badertscher, J. A., 312 Fess Ave., Bloomington	1914	1917
Beede, Joshua S., 200 Seneca St., Bantesville, Okla.	1902	1906
Behrens, Charles A., 217 Lutz Ave., W. Lafayette	1916	1917
Bennett, Lee F., 309 S. Ninth St., Janesville, Wis.	1898	1916
Benton, Geo. W., 100 Washington Sq., care American Book Co., New York, N.Y.	Charter	1896
Bigney, Andrew J., Evansville College, Evansville	Charter	1897
Blanchard, William M., DePauw University, Greencastle	1909	1914
Blatchley, W. S., 1558 Park Ave., Indianapolis	Charter	1893
Breeze, Fred J., State Normal, Muncie	1898	1910
Bruner, Henry Lane, Butler College, Indianapolis	1892	1899
Bryan, William Lowe, Indiana University, Bloomington	1893	1914
Butler, Amos W., 52 Downey Ave., Irvington, Indianapolis	Charter	1893
Carr, Ralph H., Purdue University, Lafayette	1914	1922
Cogshall, W. A., 423 S. Fess Ave., Bloomington	1905	1906
Coulter, Stanley, 213 S. Ninth St., Lafayette	Charter	1893
Culbertson, Glenn, Hanover College, Hanover	1895	1899
Cummings, Edgar Roscoe, 327 E. Second St., Bloomington	1900	1906
Deam, Charles C., Bluffton	1900	1910
Dietz, Harry F., State Conservation Commission, Indianapolis	1909	1922
Dryer, Charles R., 325 Grove St., Ft. Wayne	Charter	1897
Dutcher, J. B., 1212 Atwater Ave., Bloomington	1907	1915
Eigenmann, Carl H., 630 Atwater Ave., Bloomington	Charter	1893
Enders, Howard E., 249 Littleton St., West Lafayette	1906	1912
Evans, Percy Norton, 302 Waldron St., West Lafayette	1895	1901
Fisher, Martin L., 325 Vine St., West Lafayette	1908	1919
Foley, Arthur L., Indiana University, Bloomington	1894	1897
Hessler, Robert, 25 S. Bolton Ave., Indianapolis	Charter	1899
Hufford, Mason E., 514 S. Sluss Ave., Bloomington	1904	1916
Hurty, John E., 31 E. Eleventh St., Indianapolis	1902	1910
Hyde, Roscoe Raymond, 4101 Penhurst Ave., Baltimore, Md.	1909	1909
Jackson, Herbert S., Agricultural Exp. Station, Lafayette	1915	1919
Kern, Frank D., Dept. of Botany, State College, Pa.	1905	1912
Koch, Edward W., 24 High St., Buffalo, N. Y.	1914	1917
Logan, Wm. N., 924 Atwater Ave., Bloomington	1916	1917
Mahin, Edward G., Purdue University, Lafayette	1902	1922
Markle, M. S., Earlham College, Earlham	1910	1919
McBeth, Wm. A., 1905 N. Eighth St., Terre Haute	Charter	1904

[1] Every effort has been made to obtain the correct address of each member. In order to keep the mailing list correct, it is necessary that the secretary be informed of all changes of address. In accordance with the action of the Academy, members two years in arrears have been dropped from the roll.

[2] Date of election to Academy.

[3] Date of election to fellowship.

McBride, Robert W., 1239 State Life Bldg., Indianapolis	Charter	1916
Middleton, Arthur R., 705 Russell St., W. Lafayette	1906	1918
Moenkhaus, W. J., Indiana University, Bloomington	1893	1901
Mottier, David M., 215 Forest Place, Bloomington	Charter	1893
Naylor, Joseph P., Greencastle	Charter	1903
Nieuwland, J. A., Notre Dame University, South Bend	1908	1914
Payne, F., 620 Ballantine Road, Bloomington	1913	1916
Ramsey, Rolla R., 615 E. Third St., Bloomington	1904	1906
Rettger, Louis J., 31 Gilbert Ave., Terre Haute	1893	1896
Rothrock, David A., 1000 Atwater Ave., Bloomington	1898	1906
Scott, Will, Indiana University, 525 S. Park St., Bloomington	1905	1914
Shannon, Charles W., 518 Lahoma Ave., Norma, Okla.	Charter	1912
Smith, Charles Marquis, 152 Sheetz St., West Lafayette	1910	1912
Stoltz, Charles, 311 W. Jefferson Blvd., South Bend	1909	1919
VanHook, James M., 639 N. College Ave., Bloomington	1909	1911
Wade, Frank Bertram, Shortridge High School, Indianapolis	1903	1914
Weatherwax, Paul, 416 S. Dunn St., Bloomington	1913	1922
Williamson, E. B., Bluffton	1911	1914
Wright, John S., care Eli Lilly & Co., Indianapolis	1893	1894

NON-RESIDENT MEMBERS AND FELLOWS.

Abbott, G. A., Grand Forks, N.D., Fellow........................1908[4]
Aldrich, John Merton, Washington, D.C., Fellow..................1918
Brannon, Melvin A., Beloit, Wis.[5]
Burrage, Severance, Denver, Colo., Fellow........................1898
Campbell, D. H., Stanford, Cal.[5]
Clark, Howard Walton, U.S. Biol. Station, Fairport, Iowa........1900
Cook, Mel T., New Brunswick, N.J., Fellow.......................1902
Coulter, John M., University of Chicago, Illinois, Fellow..........1893
Davis, B. M., Oxford, Ohio.[5]
Evermann, Barton Warren, Golden Gate Park, San Francisco, Cal.[5]
Goss, William Freeman M., 61 Broadway, N.Y., Fellow............1893
Greene, Charles Wilson, 814 Virginia Ave., Columbia, Mo.[5]
Hargitt, Charles W., 909 Walnut St., Syracuse, N.Y.[5]
Hay, Oliver Perry, U.S. National Museum, Washington, D.C.......1893
Jordan, David Starr, Stanford, Cal...............................1893
Kingsley, John S., Urbana, Ill.[5]
Knipp, Charles T., 915 W. Nevada St., Urbana, Ill...............1894
MacDougal, Daniel Trembly, Tucson, Ariz.[5]
McMullen, Lynn Banks, 641 Euclid Ave., Valley City, N.D........1900
Marsters, Vernon F., Kansas City, Mo., care of C. N. Gould, Fellow..1893
Miller, John Anthony, Swarthmore, Pa., Fellow...................1904
Moore, George T., Missouri Botanical Garden, St. Louis, Mo.......1909
Noyes, William Albert, Urbana, Ill., Fellow......................1893
Ransom, James H., Detroit, Mich., Fellow........................1902
Reagan, Albert B., Cornfields, Ganado, Ariz......................1902

[4] Date of membership or fellowship.
[5] Elected previous to 1891.

Springer, Alfred, 312 E. Second St., Cincinnati, Ohio
Swain, Joseph, Swarthmore, Pa., Fellow 1898
Von Kleinsmid, R. B., Tucson, Ariz. 1920
Waldo, Clarence A., Fellow (address not known) 1893
Wiley, Harvey W., Woodward Building, Washington, D.C. 1895
Zeleny, Chas., 1003 W. Illinois St., Urbana, Ill. 1904

ACTIVE MEMBERS.

Acre, Harlan Q., Gordon, Nebr. ....1918[6]
Adams, James Edward, 419 W. Wood St., West Lafayette 1921
Adams, William B., 431 S. College Ave., Bloomington 1919
Addington, Archie, 801 Atwater Ave., Bloomington 1921
Allee, W. N., 221 E. Fourth St., Bloomington 1922
Allen, William Ray, University of Kentucky, Lexington, Ky. 1912
Allison, Luna Evelyn, 435 Wood St., West Lafayette 1908
Anderegg, Frederick O., 322 Waldron St., West Lafayette 1918
Anderson, Flora Charlotte, 327 S. Henderson St., Bloomington 1914
Armington, John H., U.S. Weather Bureau, Indianapolis 1921
Atkinson, F. C., 2534 Broadway, Indianapolis 1914
Auble, Robert N., 409 N. Wolcott St., Indianapolis 1922
Baker, Lora M., 804 S. Grant St., Bloomington 1920
Baker, Wm. F., Box 586, Carmel 1914
Balcom, Stephen F., 3634 Birchwood Ave., Indianapolis 1920
Baldwin, Ira L., 849 N. Salisbury St., West Lafayette 1919
Barnett, Horace L., Indiana University, Bloomington 1922
Barnhill, Dr. T. F., Indiana Univ. School of Medicine, Indianapolis. 1916
Barr, Harry L., Buckley, Ill. 1911
Barrett, Edward, State Geologist, Indianapolis 1911
Beals, Colonzo, 103 Russell St., Hammond 1915
Becktel, Albert R., 209 W. College St., Crawfordsville 1920
Beecher, Alva, 1010 E. Pike St., Crawfordsville 1922
Beeson, K. E., 427 State St., West Lafayette 1922
Begeman, Hilda, 24 Linden St., Wellesley, Mass. 1919
Bell, Alva Marie, 511 Smith Ave., Bloomington 1922
Berg, George F., Jr., 3518 Balsam Ave., Indianapolis 1922
Berteling, Dr. J. B., 228 Colfax Ave., South Bend 1914
Black, Homer F., 2721 S. Michigan Ave., Chicago, Ill. 1916
Bockstahler, Lester, 101 Haven House, Evanston, Ill. 1920
Bodine, Mrs. Emma, 4 Mills Place, Crawfordsville 1921
Bolen, Homer R., 314 S. Grant St., Bloomington 1922
Bond, Dr. Charles S., 112 N. Tenth St., Richmond 1900
Bond, Dr. George S., 112 N. Tenth St., Richmond 1916
Boots, Edwin B., 125 N. 6th St., West Terre Haute 1922
Bourke, Adolphus A., 2304 Liberty Ave., Terre Haute 1909
Brewer, P. H., 145 E. Oak St., West Lafayette 1921
Brock, James E., Sweetser 1922

[6] Date of membership in the Academy.

Brosey, Charles L., 766 W. Drive, Woodruff Place, Indianapolis....1922
Brossmann, Charles, 1503 Merchants Bank Bldg., Indianapolis.....1909
Bruce, Edwin M., 2108 N. Tenth St., Terre Haute.................1918
Burton, Everett T., 3100 Broadway, New York, N.Y................1920
Bushnell, T. M., Agr. Exp. Sta., West Lafayette..................1922
Bybee, Halbert P., University Station, Austin, Texas..............1912
Byers, Cecil W., Box 332, University Station, Grand Forks, N.D....1919
Cain, Stanley A., 80 N. Holmes St., Indianapolis..................1921
Campbell, Elmer G., 220 Sylvia St., West Lafayette...............1919
Campbell, Marion S., 29 N. Hawthorne Lane, Indianapolis.........1921
Canis, Edward N., Route A-2, Box 372-A, Indianapolis............1909
Caparo, Jose Angel, Notre Dame University, South Bend..........1914
Carter, Edgar B., 4555 Central Ave., Indianapolis................1918
Cassady, Emil V., 1841 C.D., Woodruff Place, Indianapolis........1920
Cavins, Alexander, 1232 N. Alabama St., Indianapolis............1920
Chansler, Elias J., Bicknell......................................1895
Chapman, Edgar K., 506 S. Grant St., Crawfordsville.............1911
Chitty, Ethel, Indiana State Normal, Muncie.......................1922
Christy, O. B., Indiana State Normal, Muncie.....................1919
Clark, Jediah H., 126 E. Fourth St., Connersville..................1909
Clay, Mrs. Celia, 320 N. State St., Kendallville...................1922
Cleveland, Clarence R., Purdue Agricultural Exp. Sta., Lafayette..1921
Cloves, G. H. A., Eli Lilly & Co., Indianapolis...................1920
Coggeshall, Lowell, 339 S. Walnut St., Bloomington...............1921
Conner, S. D., 204 S. Ninth St., Lafayette........................1912
Cook, Rolla V., 600 E. Second St., Bloomington...................1922
Coryell, Noble H., Columbia University, New York, N. Y.........1914
Cottman, Evans W., Lanier Place, Madison.........................1921
Cox, C. F., 528 N. Oxford St., Indianapolis.......................1922
Crozier, Alice M., 312 Kenmore Rd., Indianapolis..................1921
Curtis, Lila C., 406 N. Fess Ave., Bloomington....................1920
Danglade, Ernest, Vevay 1920
Davis, Charles, 217 Sylvia St., West Lafayette....................1922
Davis, Hugh L., 423 Vine St., West Lafayette......................1921
Davis, John J., Purdue University, Lafayette......................1920
Davis, Ward B., Botany Bldg., University of Chicago, Chicago, Ill...1921
Dean, Miss Grace, French Lick.....................................1922
Dean, John C., University Club, Indianapolis.....................1914
deForest, Howard, Indianapolis Normal School, Indianapolis.......1921
Demaree, Delzie, Benham..1920
Deppe, C. A., Franklin...1911
Derby, Ira Harris, 5460 University Ave., Indianapolis.............1920
Deuker, Henry W., Jr., Y.M.C.A., Indianapolis....................1921
Dietz, Chas. D., 3121 Fairfield Ave., Ft. Wayne.................
Dietz, Emil, 334 Congress Ave., Indianapolis......................1921
Diggs, John C., 54 Kealing Ave., Indianapolis....................1920
Dilts, Charles D., 3121 Fairfield Ave., Ft. Wayne.................1920
Doan, Martha, Earlham 1896
Doan, Richard L., 802 E. Third St., Bloomington..................1922

Dolan, Joseph P., Syracuse....................................1895
Domroese, Fred C., 815 W. Main St., Crawfordsville..............1920
Donahue, Joseph N., Columbia University, Portland, Ore. 1920
Douglass, Benjamin W., Trevlac 1916
Downhour, Elizabeth, 1817 Broadway, Indianapolis...............1915
Dugan, Elizabeth, 717 N. Tremont St., Indianapolis..............1922
Dunham, David H., 429 Main St., West Lafayette...............1920
Earp, Samuel E., 634 Occidental Bldg., Indianapolis..............1909
East, Mrs. Pearl W., Gilman, Iowa..............................1920
Eaton, Dunwald L., Indiana Central College, Indianapolis.........1922
Edmonson, Clarence E., 822 Atwater Ave., Bloomington...........1912
Eisenhard, Geo. B., Culver Military Academy, Culver............1921
Eisenhard, Mrs. Geo. B., Culver................................1921
Eldred, Frank P., 2823 N. Delaware St., Indianapolis............1918
Elkin, Sarah K., 612 Harvey Ave., West Lafayette...............1921
Emerson, Dr. Charles P., 602 Hume-Mansur Bldg., Indianapolis....1915
Estabrook, Arthur H., Board of State Charities, Indianapolis......1916
Etter, Austin, 931 Cass Ave., S. E., Grand Rapids, Mich.........1920
Evans, Samuel G., 1452 Upper Second St., Evansville............1891
Feldman, Horace W., 138 Chauncey Ave., West Lafayette.........1920
Ferguson, Luther S., State Geologist's Office, Indianapolis.........1920
Foresman, George K., 110 S. Ninth St., Lafayette...............1914
Franklin, Fred F., Washington..................................1921
Friesner, Ray C., Butler College, Indianapolis....................1919
Froning, Henry B., 415 Pokagon St., South Bend.................1920
Fugate, Mary, 2525 Park Ave., Indianapolis.....................1920
Fuller, F. D., 3021 College Ave., Bryan, Texas...................1910
Funk, Dr. Austin, 404 Spring St., Jeffersonville.................1895
Galloway, Jesse J., Geology Dept., Columbia Uni., New York, N. Y..1910
Gantz, Richard A., State Normal School, Muncie.................1920
Gardner, Max William, Purdue Agr. Exp. Station, Lafayette......1919
Garver, Frederick R., 510 E. 5th St., Bloomington...............1922
Gatch, Willis D., 605 Hume-Mansur Bldg., Indianapolis..........1915
Gates, Florence A., 3435 Detroit Ave., Toledo, Ohio..............1909
Gayler, Dona G., 200 N. Sixth St., Terre Haute..................1920
Gidley, William F., 276 Littleton St., West Lafayette.............1914
Gillum, Robert G., Indiana State Normal, Terre Haute............1913
Gingery, Walter G., Shortridge High School, Indianapolis........1918
Goldsmith, William M., Southwestern College, Winfield, Kansas....1914
Graves, Benjamin H., 604 E. Market St., Crawfordsville..........1920
Greene, Frank C., 1434 Cincinnati Ave., Tulsa, Okla..............1908
Gregory, Charles T., 1022 First St., W. Lafayette.................1922
Guernsey, E. Y., 120½ W. 46th St., Los Angeles, Calif...........1921
Guthrie, W. A., 10 E. Market St., Indianapolis...................1920
Hadley, Joel W., 1127 Fairfield Ave., Indianapolis................1919
Hagey, G. L., 219 Wiggins St., West Lafayette....................1920
Hanna, U. S., Atwater Ave., Bloomington.........................1914
Hansen, Albert A., Purdue Agri. Exp. Station, Lafayette..........1921
Hansford, Hazel I., Southeastern Hosp. for Insane, North Madison..1916

Happp, William, South Bend....................................1914
Harding, Charles F., 503 University St., West Lafayette..........1918
Hardy, Eugene H., 1230 S. Keystone Ave., Indianapolis...........1920
Harmon, Paul M., 311 E. South Ave., Bloomington..............1915
Hassenzahl, Elizabeth, 424 Vine St., West Lafayette..............1921
Hedebol, Frederick C. N., 809 W. Grand Blvd., Springfield, Ill.....1920
Heimburger, Harry V., Hamline Ave., St. Paul, Minn............1912
Heimlich, Louis F., 495 Littleton St., West Lafayette............1914
Hendricks, Victor K., 131 N. Eighth St., Terre Haute............1900
Hess, Walter N., S. College Ave., Greencastle....................1917
Hills, Donald H., 2127 Talbott Ave., Indianapolis................1922
Hinman, Jack J., University of Iowa, Iowa City, Iowa............1912
Hoffer, Geo. N., 434 Littleton St., West Lafayette................1909
Hoffman, A. C., 920 E. Drive, Woodruff Place, Indianapolis........1922
Hoffman, G. L., Western Pennsylvania Hospital, Pittsburg, Pa......1911
Hole, Allen D., 615 National Road West, Richmond.............1901
Howick, Howard, Indiana State Normal, Muncie.................1921
Howlett, Berton A., 503 Elm St., Valparaiso.....................1919
Huber, Leonard L., Hanover.....................................1915
Hufferd, Ralph, Greencastle.......................................1920
Hull, Julia, St. Anne, Ill..1919
Hutchinson, Emory, Norman Station..............................1915
Hutton, Joseph G., State College, Brookings, S. D................1911
Hyslop, George H., 143 Twenty-second St., Long Island, N. Y.......1914
Irving, Thomas P., Notre Dame University, South Bend..........1914
Jackson, James W., Central High School, Chattanooga, Tenn......1918
James, Charles M., 443 Wood St., West Lafayette................1921
James, Evalyn G., 144 Butler Ave., Indianapolis..................1919
Jensen, Howard E., 360 Downey Ave., Indianapolis................1921
Kaczmarek, Regidius M., Box 54, Notre Dame Uni., South Bend....1914
Kantor, Jacob R., 645 N. Walnut St., Bloomington................1920
Katterjohn, Mable C., Lynnville.................................1920
Kendrick, James B., Purdue Agri. Exp. Station, Lafayette.........1921
Kennedy, Clarence H., Ohio State Univ., Columbus, Ohio.........1922
Kiester, Jackson A., 300 S. Green St., Crawfordsville............1922
Kinsey, Alfred C., S. Park Ave., Bloomington...................1920
Klipinger, Walter C., 2234 Park Ave., Indianapolis..............1922
Knecht, Christian, 207 N. Dunn St., Bloomington.................1922
Knotts, Armanis F., Anglis, Fla.................................1917
Koch, E. W., 24 High St., U. S. Medical Dept., Buffalo, N. Y......1914
Kohl, Edwin J., 218 Fowler Ave., West Lafayette................1917
Lanham, Miss Bess, 610 E. Wabash Ave., Crawfordsville.........1922
Larrimer, Walter H., Box 95, West Lafayette....................1921
Lieber, Richard, State House, Indianapolis.......................1919
Liston, Jesse G., R.F.D. 2, Lewis................................1916
Ludwig, C. A., Clemson College, S.C.............................1911
Ludy, Llewellyn V., 600 Russell St., West Lafayette..............1908
Luten, Daniel B., 1056 Lemcke Annex, Indianapolis...............1918
Lyon, Marcus Ward, Jr., 214 LaPorte Ave., South Bend..........1922
Mains, E. B., 212 S. Grant St., W. Lafayette.....................1916

Maloney, Wm., Notre Dame University, South Bend..............
Malott, Burton J., Technical High School, Indianapolis...........1916
Malott, Clyde A., 521 E. 2nd St., Bloomington....................1914
Malott, Ruth Boyd, 629 Carlisle Place, Indianapolis...............1914
Mannfeld, George N., 1235 Central Ave., Indianapolis............1922
Martin, Elsie S., 134 N. Drexel St., Indianapolis.................1922
Martin, Mrs. Viva Dutton, 134 N. Drexel St., Indianapolis.........1922
Mason, Thomas E., 130 Andrew Place, West Lafayette............1905
McAvoy, Miss Blanche, Muncie..................................1921
McCarty, Morris, High School, Montmorenci....................1917
McDonald, Clinton C., 415 S. Dunn St., Bloomington............1922
McDonald, Doloris, 526 E. 5th St., Bloomington..................1921
McEachron, Karl B., 335 Lutz Ave., West Lafayette..............1921
McGavran, Edward, Downey Ave., Indianapolis..................1921
Mellon, M. G., 403 Russell St., West Lafayette...................1921
Michael, Lyle Jordan, Indiana Central College, Indianapolis......1922
Miller, Fred A., Eli Lilly Co., Greenfield.........................1908
Miller, John W., 115 E. Columbia St., West Lafayette.............1919
Montgomery, Basil E., Poseyville.................................1922
Montgomery, H. T., 208 Dean Building, South Bend..............1898
Moore, John Irwin, Owensville.....................................1922
Moore, Kenneth W., 125 Downey Ave., Indianapolis...............1921
Moorhead, John G., 124 DeHart St., West Lafayette..............1922
Morgan, Frank W., Science Hall, Valparaiso.......................1920
Morgan, Will, University Heights, Indianapolis....................1920
Morrison, Harold, Bureau of Entomology, Washington, D.C........1910
Morrison, Louis A., care Edward Morrison, Mich. Agric. Coll., East Lansing, Mich. 1917
Muldoon, Hugh C., 502 Main St., Valparaiso......................1920
Mullendore, Miss Naomi, Franklin 1922
Munro, George W., 202 Waldron St., West Lafayette...............1917
Myers, B. D., 321 N. Washington St., Bloomington................1911
Nelson, Ralph E., 232 Littleton St., West Lafayette..............1914
Nicholson, Thomas E., 519 N. Fess Ave., Bloomington...........1918
Niles, Edward H., 4450 Guilford Ave., Indianapolis................1920
Noble, Willis Bernard, Box 95, West Lafayette.....................1922
Noyes, Harry A., State Dept. of Agriculture, Lansing, Mich.......1916
Oberholser, Harry C., U. S. National Museum, Washington, D.C.....1914
O'Neal, Claude E., Forrest Ave., Delaware, Ohio.................1912
Orahood, Harold, Union Mills.......................................1914
Orton, Clayton R., State College, Pa...............................1910
Osbun, Clifford Leroy, 201 Russell St., West Lafayette............1922
Owen, D. A., 200 S. State St., Franklin............................1885
Painter, Henry R., Box 95, West Lafayette.........................1921
Payne, Mary G., 303 S. Downey Ave., Indianapolis................1922
Pearson, George B., Box 95, West Lafayette......................1921
Pearson, Nathan E., Indiana University, Bloomington.............1922
Peffer, Harry C., 1022 Seventh St., West Lafayette...............1914
Petry, Edward J., 625 Twelfth Ave., Brookings, S. D.............1911
Pickett, Fermen L., Station 36, Pullman College, Washington......1909

Pinkerton, Earl, Box 447, Walters, Okla........................1916
Pitkin, Edward M., 519 N. College St., Bloomington.............1922
Pollard, Cash B., 419 W. Wood St., West Lafayette...............1921
Prentice, Burr N., 400 Russell St., West Lafayette...............1915
Price, Walter A., 123 Sheetz St., West Lafayette.................1919
Proulx, Edward G., 111 Waldron St., West Lafayette.............1918
Raab, Albert L., 1351 Consolidated Bldg., Indianapolis............1921
Rawles, William P., 924 E. Third St., Bloomington...............1920
Records, Ralph L., Edinburg.....................................1920
Reeves, John R., 414 E. Third St., Bloomington..................1920
Reinhard, Herbert F., Room 152, State House, Indianapolis........1921
Richards, Dr. and Mrs. Aute, University of Oklahoma, Norman, Okla. 1916
Ridgway, Robert, 1030 S. Morgan St., Olney, Ill...................1920
Rifenburgh, S. A., Valparaiso....................................1916
Riley, Katherine, 56 Whittier Place, Indianapolis.................1916
Roark, Louis, Box 1266, Okmulgee, Okla..........................1917
Roberts, Chester R., 901 E. Jefferson St., Franklin...............1919
Roberts, Harry John, Route A., Lafayette.........................1922
Robertson, Pay S., 702 Evergreen St., West Lafayette............1922
Senour, Frank C., 323 N. Grant St., Bloomington................1922
Sheak, Wm. H., Ijamsville......................................1916
Sherman, George W., 8 Murdock Flats, West Lafayette...........1918
Shonle, Horace A., Eli Lilly & Co., Indianapolis.................1919
Showalter, Ralph W., Eli Lilly & Co., Indianapolis...............1915
Silvey, Oscar W., College Station, Texas.........................1909
Smith, Charles Piper, 354 S. Tenth St., San Jose, Calif 1903
Smith, Ernest R., Greencastle....................................1921
Smith, John C., Route 6, Franklin................................1919
Smith, Lee T., R.F.D. 7, Bloomington.............................1922
Smith, Paul R., University of Pennsylvania, Philadelphia, Pa......1920
Snodgrass, Robert E., U. S., Agricultural Station, Wallingford, Conn. 1917
Spitzer, George, 1000 Seventh St., West Lafayette................1909
Spong, Philip, 3873 E. Washington St., Indianapolis..............1916
Stacy, Allan R., 1555 Ashland Ave., Indianapolis.................1921
Stirrett, George M., 521 State St., West Lafayette................1922
Stone, Ralph B., 307 Russell St., West Lafayette.................1914
Strickler, Alvin, Evansville College, Evansville..................1922
Sulzer, Elmer G., Madison......................................1918
Suter, E. M., 1437 Broadway, Ft. Wayne.........................1920
Tasker, Roy C., 612 Anderson St., Greencastle....................1922
Tatlock, Myron W., Shortridge High School, Indianapolis..........1918
Taylor, George O., 502 S. Sluss Ave., Bloomington...............1922
Telfer, Margaret, 403 W. 5th St., Bloomington...................1921
Terry, Dr. Oliver P., 215 Sheetz St., West Lafayette..............1914
Test, Louis A., 511 Russell St., West Lafayette...................1918
Tetrault, Philip A., 607 University St., West Lafayette...........1914
Tevis, Emma L., 122 W. Eighteenth St., Indianapolis..............1916
Thompson, Clem O., Hanover....................................1911

Thompson, James T., 334 Lafayette Ave., Lebanon................1920
Thornburn, A. D., 42 E. 37th St., Indianapolis..................1909
Thrasher, Mrs. John R., Apt. 1, 3805 N. Delaware St., Indianapolis.1921
Treat, Frank M., Atwater Ave., Bloomington...................1920
Troop, James, 123 Sheetz St., West Lafayette.....................1914
Tucker, William Motier, 505 Ballantine Road, Bloomington........1910
Turley, Harold E., Am. Baking Inst., Chicago, Ill................1921
Turner, B. B., 1017 Park Ave., Indianapolis.......................1916
Turner, William P., 222 Lutz Ave., West Lafayette................1908
Twitty, Victor, 4922 Central Ave., Indianapolis..................1921
Van Nuys, W. C., Newcastle.....................................1914
Visher, Stephen S., 817 E. 2nd St., Bloomington.................1919
Voorhees, Herbert S., 804 Wildwood Ave., Ft. Wayne...........1896
Wallace, Frank N., Dept. of Entomology, State House, Indianapolis.1920
Ward, Mary Mallory, 405 E. William St., Kendallville.............1922
Weems, Mason L., 102 Greenfield Ave., Valparaiso................1919
Wenninger, Rev. Francis J., Notre Dame University, South Bend..1920
Wiancko, Alfred T., 230 S. Ninth St., Lafayette..................1909
Wildman, Ernest A., Earlham....................................1918
Wiley, Ralph B., 227 Russell St., West Lafayette.................1914
Wilhite, Miss Ida B., Butler College, Indianapolis...............1921
Wilkinson, Paul D., 300 S. 4th St., Terre Haute.................1921
Williams, A. A., Valparaiso.....................................1916
Williamson, Jesse H., Bluffton..................................1921
Wilson, Arthur J., 901 W. Wabash St., Crawfordsville............1920
Wilson, E. R., 2830 E. Vermont St., Indianapolis.................1922
Wilson, Mrs. Etta, 9077 Clarendon Ave., Detroit, Mich............1915
Wilson, Geo. B., 427 State St., West Lafayette...................1921
Wilson, Ira T., 521 Kirkwood Ave., Bloomington..................1919
Winkenhofer, Walter, Huntingburg..............................1920
Witmer, Samuel W., 1405 Ninth St., Goshen.....................1921
Wolfe, Harold E., 314 N. Washington St., Bloomington............1920
Wood, Harry W., 5923 Winthrop Ave., Chicago, Ill..............1912
Woodruff, Albert E., University of Chicago, Chicago, Ill..........1921
Young, Gilbert A., 739 Owen St., Lafayette......................1908
Young, Herman, 602 N. College St., Bloomington.................1922
Young, Paul A., 605 W. University Ave., Urbana, Ill..............1920
Yuncker, Truman G., 203 Wood St., Greencastle.................1919
Zebrowski, George, 244 Harrison St., West Lafayette..............1920
Zehring, William A., 303 Russell St., West Lafayette..............1907
Zerfas, Leon G., Indiana University Medical School, Indianapolis...1921
Zierer, Clifford M., Indiana University, Bloomington.............1922

SUMMARY OF MEMBERSHIP.

Fellows	58
Members, active	325
Members and Fellows, non-resident	31
Total	414